SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Special Features

Chemical Oxygen Use—McKinney and Conway

Detergent Research—Moss

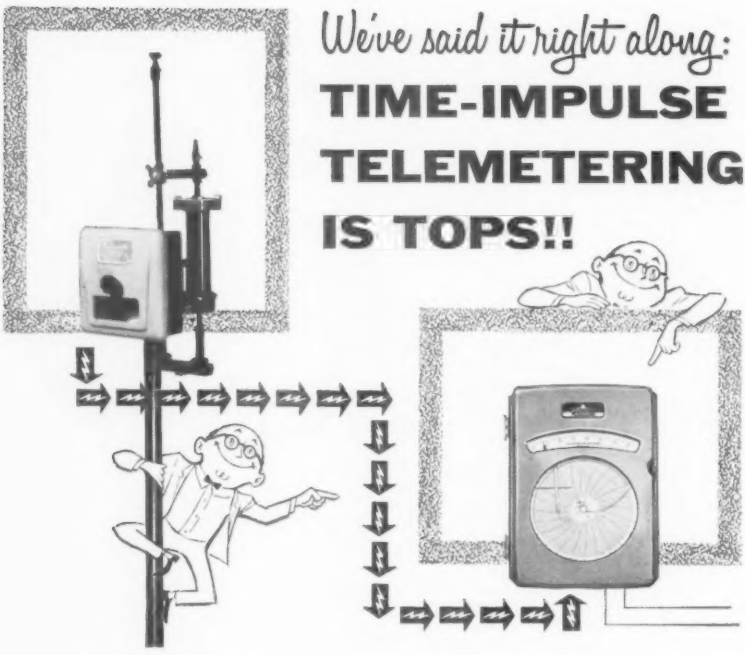
Planned Water Reclamation—Rawn and Bowerman

Pulp Mill Wastes—Pearman and Burns

Industrial Pollution Abatement—Poole and Miller

Initial Digester Start-Up—Shafer

OCTOBER, 1957—VOL. 29, No. 10



We've said it right along:

TIME-IMPULSE TELEMETERING IS TOPS!!

...AND YOU'VE SAID IT TOO...WITH YOUR ORDERS!!

In Builders Chronoflo Telemetering Systems: The transmitting and receiving reactions depend only upon the *positively* controlled duration of regular electric circuit closures and *nothing* more.

*The Telemeter is a pure, *positive-action* positioning system.

- It does *not* have to *translate* units of electric measurement into terms of rate of flow or other factors measured.
- It requires *no* relatively delicate electric components.
- It *doesn't employ* a series of contact rods "shorted out" by step-by-step action of rising mercury.
- It is *not affected* by normally encountered induced voltages.
- Receiver *accuracy not affected* by room temperature, line pressure, duration of "down time", and similar factors.

*The Chronoflo Receiver is *not* inferentially positioned except with respect to time duration of the Transmitter signals.

These are *only a few* reasons why time-impulse telemetering is "Tops". Let the company which pioneered this system over 25 years ago and has the experience gained in engineering thousands of installations give you complete proof of its dependability and accuracy.

Request Bulletin 230-H4A. Write Builders-Providence, Inc., 368 Harris Ave., Providence 1, R. I.

BUILDERS-PROVIDENCE
DIVISION OF
B-I-F INDUSTRIES
BIF METERS FEEDERS CONTROLS

Mishawaka, Indiana Sewage Treatment Plant — Charles W. Cole & Son, Consulting Engineer

- Uninterrupted, dependable sewage aeration.
- Continuous highest oxygenation efficiency available as required now or in the future.
- Low maintenance, economical Super Clean Air Filter System allows less than 0.09 mg. of dirt per thousand cubic feet of air, minimizing particulate clogging.

OVER 10,000 "SWINGS" INSTALLED IN MORE THAN 300 PLANTS TO DATE

CHICAGO PUMP COMPANY

Sewage and Industrial Waste Equipment

Subsidiary of Food Machinery & Chemical Corporation

fmc

622 Diversey Parkway
Chicago 14, Illinois

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

PRESIDENT

EMIL C. JENSEN, Chief
Division of Engineering and Sanitation
State Department of Health
Seattle 4, Washington

VICE-PRESIDENT

KENNETH S. WATSON, Consultant
Water Management and Waste Control
General Electric Company
202 State Street
Schenectady 5, New York

TREASURER

W. W. DEBERARD
Deputy Commissioner for Water
Chicago 2, Illinois

EXECUTIVE SECRETARY-EDITOR

RALPH E. FUHRMAN
4435 Wisconsin Ave., N.W.,
Washington 16, D. C.

ADVISORY EDITOR

F. W. MOHLMAN, Director of Laboratories
Metropolitan Sanitary District of Greater Chicago
Chicago 11, Illinois

DIRECTORS

Ex-Officio: GEORGE W. MARTIN
Alabama: J. L. CROCKETT, JR. (1957)
Arizona: JOHN A. CAROLLO (1958)
Arkansas: LOREN R. HEIPLE (1958)
California: R. T. ANTRIM (1959); J. H. PETERSON (1958)
Canada: CLARENCE S. ANDERSON (1958)
Central States: M. L. ROBINS (1957); O. J. MUEGGE (1959)
Dakota: L. W. VEIGEL (1958)
Federal: MARK HOLLIS (1959)
Florida: J. W. WAKEFIELD (1959)
Georgia: R. E. STIEMKE (1959)
Germany: DR. ING. F. SCHMITZ-LENDERS (1959)
Inst. of Pub. Hlth. Eng. (Eng.): M. A. KERSHAW (1959)
Inst. Sew. Pur. (Eng.): M. LOVETT (1959)
Iowa: H. S. SEIDEL (1959)
Kansas: MYRON NELSON (1957)
Kentucky-Tennessee: GRANT S. BELL (1958)
Louisiana: J. L. LOVE (1958)
Maryland-Delaware: ROY H. RITTER (1957)
Michigan: R. A. GREENE (1958)
Missouri: J. K. SMITH (1957)
Montana: D. H. DENMAN (1959)
Nebraska: DAVID R. HILL (1958)
New England: WILLIAM S. WISE (1957)
New Jersey: SOL SEID (1957)
New York: A. J. FISCHER (1957); UHL T. MANN (1959)
North Carolina: E. C. HUBBARD (1958)
Ohio: G. A. HALL (1957)
Oklahoma: G. L. MORRIS (1959)
Pacific Northwest: H. L. THOMPSON (1959)
Pennsylvania: ROY F. WESTON (1958); T. R. HASELTINE (1959)
Puerto Rico: R. DOMENECH (1959)
Rocky Mountain: B. V. HOWE (1957)
South Carolina: E. D. FRY (1958)
Sweden: G. AKERLINDH (1959)
Switzerland: PIERCE WILDI (1957)
Texas: C. H. CONNELL (1957)
Virginia: F. H. MILLER (1959)
West Virginia: O. C. THOMPSON (1959)
At Large: R. R. KENNEDY (1957)
At Large: RAY E. LAWRENCE (1958)
At Large: W. W. GILLESPIE (1959)
W. and S. Wks. Mfgrs.: G. W. KELSEY (1957)
W. and S. Wks. Mfgrs.: T. T. QUIGLEY (1958)
W. and S. Wks. Mfgrs.: M. SPIEGEL (1959)

SEWAGE AND INDUSTRIAL WASTES

REG. U. S. PAT. OFF.

A monthly Journal devoted to the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes, and the design, construction, operation and management of such works.

PUBLICATION OFFICE

Prince and Lemon Sts., Lancaster, Pa.

EDITORIAL AND EXECUTIVE OFFICES

4435 Wisconsin Ave., N.W., Washington 16, D. C. Send all manuscripts, advertising copy, subscriptions, address changes, etc., to this address.

SUBSCRIPTION RATES

Members of local sewage works associations affiliated with the Federation, $5.00 per year.

Non-members: U. S. and Canada, $7.50 per year; other countries, $9.00. (Foreign subscriptions must be accompanied by International Money Order.)

Single copies: United States $1.00 each; Foreign, $1.25 each.

CLAIMS

No claims will be allowed for copies of Journals lost in the mails unless such claims are received within sixty (60) days of the date of issue and no claims will be allowed for issues lost as a result of insufficient notice of change of address. "Missing from files" cannot be accepted as the reason for honoring a claim.

MAILING PERMIT

Entered as second-class matter, May 7, 1934, at the post office at Lancaster, Pa., under the Act of March 3, 1879. Additional entry at Washington, D. C. Accepted for mailing at the special rate of postage provided for in the Act of February 28, 1925, embodied in paragraph (d-2), Section 34.40, P. L. & R. of 1948, authorized October 4, 1945.

REFERENCE SERVICE

Sewage and Industrial Wastes is indexed regularly by *Industrial Arts Index* and *Engineering Index*.

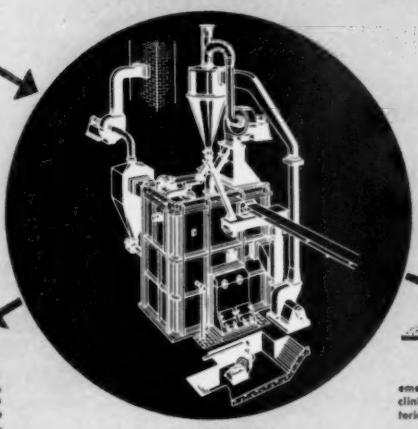
Microfilm copies of this Journal may be procured from University Microfilms, Ann Arbor, Mich. This service is limited to regular subscribers only.

The C-E Raymond System —

the MODERN method of SLUDGE DISPOSAL

SLUDGE

as a vacuum filter cake or thickened sludge from any type of sewage treatment process enters the C-E Raymond System.



SOIL CONDITIONER

emerges as a desirable product, easy to handle, exceptionally rich in humus, and containing the trace elements found in good topsoil.

and/or

ASH

emerges as a fine dust, free from clinker and unburned organic materials.

The C-E Raymond System is the most popular . . . most versatile on the market today. It combines the principles of Flash Drying and Incineration in a single compact system that allows you to Flash Dry or Incinerate sewage sludge alternately or concurrently. It is available with a high temperature deodorization system that assures odor-free operation.

Flash Drying by the C-E Raymond System is a continuous process in which vacuum filtered sludge — if uncontaminated with undesirable industrial wastes — is efficiently heat dried to a marketable soil conditioner retaining all its original nitrogen, but eliminating the objectionable qualities of the original wet sludge. In a well designed and operated "activated plant" the revenue from the sale of soil conditioner is sufficient to cover a sizable part of the plant operating costs.

Where the production of soil conditioner is not desired or the sludge is unsuitable, it is flash dried and then completely burned in suspension to an easily disposable, sterile ash.

The services of C-E specialists are available to help you plan for the end of atmospheric or stream pollution in your community, as has been done in so many others. For specific recommendations on the most practical answer to your sludge disposal problems, get in touch with the Combustion office nearest you. B-860A

also flash drying and incineration systems for industrial waste disposal

COMBUSTION ENGINEERING

RAYMOND DIVISION

1315 North Branch Street, Chicago 22, Illinois

Eastern Office: 200 Madison Ave., New York 16, N. Y. *Western Office:* 510 W. Sixth St., Los Angeles 14, Calif.

CANADA: COMBUSTION ENGINEERING — SUPERHEATER, LTD., MONTREAL

FSIWA MEMBER ASSOCIATIONS

Alabama Water and Sewage Assn.*
PROF. R. T. TINDAL, *Sec.*
Alabama Water and Sewage Assn.
P. O. Box 1224
University, Ala.

Arizona Sewage and Water Works Assn.*
STANFORD I. ROTH, *Sec.-Treas.*
813 Jefferson St.
Phoenix, Ariz.

Arkansas Water and Sewage Conf.*
DR. C. W. OXFORD, *Sec.-Treas.*
University of Arkansas
Fayetteville, Ark.

California Sewage and Industrial Wastes Assn.
ROBERT J. BARLETTA, *Sec.-Treas.*
719 South Loara St.
Anaheim, Calif.

Canadian Institute on Sewage and Sanitation
DR. A. E. BERRY, *Sec.-Treas.*
Administrative Office
72 Grenville St.
Toronto, Ontario, Canada

Central States Sewage and Industrial Wastes Assn.
SCOTT A. LINSLEY, *Sec.-Treas.*
1269 W. Como Blvd.
St. Paul 3, Minn.

Dakota Water and Sewage Works Conf.

North Dakota Section*
W. VAN HEUVELEN, *Sec.-Treas.*
c/o State Dept. of Health
Bismarck, N. Dak.

South Dakota Section*
CHARLES E. CARL, *Sec.-Treas.*
c/o Div. of Sanitary Engineering
State Board of Health, Pierre, S. Dak.

Federal Sewage Research Assn.
RALPH HOLTJE, *Sec.-Treas.*
Public Health Service
Room 4123, South HEW Bldg.
Washington 25, D. C.

Florida Sewage and Industrial Wastes Assn.
RALPH H. BAKER, JR., *Sec.-Treas.*
State Board of Health
P. O. Box 210, Jacksonville 1, Fla.

Georgia Water and Sewage Assn.*
A. T. STOREY, *Sec.-Treas.*
1210 Hemphill Ave., N.W.
Atlanta, Ga.

(Germany) Abwassertechnische Vereinigung
OTTO PALLASCH, *Sec.-Treas.*
Theaterstrasse 24
Bonn, Germany

Institute of Sewage Purification
W. F. A. SNOOK, *Sec.*
10, Cromwell Place
South Kensington
London, S. W. 7, England

Institution of Public Health Engineers
ERNEST V. BALSOM, *Secretary*
118 Victoria St.
Westminster, S. W. 1, London, England

Iowa Sewage and Industrial Wastes Assn.
L. F. SKORCZESKI, *Sec.-Treas.*
207 South 15th Ave.
Marshalltown, Iowa

Kansas Sewage and Industrial Wastes Assn.
JAMES F. AIKEN, *Sec.-Treas.*
407 City Building
Wichita, Kansas

Kentucky-Tennessee Industrial Wastes and Sewage Works Assn.
S. LEARY JONES, *Sec.-Treas.*
602 Cordell Hull Bldg., Nashville 3, Tenn.

Louisiana Conference on Water Supply and Sewerage*
GEORGE H. WEST, *Sec.-Treas.*
P. O. Box 15, Water Dept., Lake Charles, La.

Maryland-Delaware Water and Sewage Assn.*
W. M. BINGLEY, *Sec.-Treas.*
2411 N. Charles St., Baltimore 18, Md.

Michigan Sewage and Industrial Wastes Assn.
D. M. PIERCE, *Sec.-Treas.*
Michigan Dept. of Health
Room 334, Admin. Bldg., Lansing 4, Michigan

Missouri Water and Sewerage Conf.*
WARREN KRAMER, *Sec.-Treas.*
State Office Bldg., Fourth Floor
Jefferson City, Mo.

Montana Sewage and Industrial Wastes Assn.
HARVEY W. TAYLOR, *Sec.-Treas.*
Morrison & Maierle Inc.
Helena, Montana

Nebraska Sewage and Industrial Wastes Assn.
V. J. LECHTENBERG, *Sec.-Treas.*
614 Standard Oil Bldg., Omaha, Neb.

New England Sewage and Industrial Wastes Assn.
EARL R. HOWARD, *Sec.-Treas.*
Bureau of Public Works
115 Broad St., Hartford, Conn.

New Jersey Sewage and Industrial Wastes Assn.
MICHAEL S. KACHORSKY, *Sec.-Treas.*
P. O. Box 68, Manville, N. J.

New York Sewage and Industrial Wastes Assn.
RALPH C. SWEENEY, *Secretary*
c/o State Dept. of Health
21 N. Broadway, White Plains, N. Y.

North Carolina Sewage and Industrial Waste Assn.
W. E. LONG, JR., *Sec.-Treas.*
Box 2091, Raleigh, N. C.

Ohio Sewage and Industrial Wastes Treatment Conf.
CLEAMON E. LAY, *Sec.-Treas.*
Rm. 517, 101 N. High St., Columbus 15, Ohio

Oklahoma Water, Sewage and Industrial Wastes Conf.*
H. M. CRANE, *Sec.-Treas.*
3400 Northeastern, Oklahoma City 5, Okla.

Pacific Northwest Sewage and Industrial Wastes Assn.
GILBERT H. DUNSTAN, *Sec.-Treas.*
P. O. Box 176, Pullman, Wash.

Pennsylvania Sewage and Industrial Wastes Assn.
J. R. HARVEY, *Sec.-Treas.*
c/o Pennsylvania Dept. of Health
916 Diamond, Meadville, Pa.

Puerto Rico Water and Sewage Works Assn.
ROBERT J. AULD, *Sec.-Treas.*
c/o Puerto Rico Aqueduct and Sewer Service
Box 2832, San Juan 12, Puerto Rico

Rocky Mountain Sewage and Industrial Wastes Assn.
JOHN R. PETERSON, *Sec.-Treas.*
376 City and County Bldg., Denver 2, Colorado

South Carolina Water and Sewage Works Assn.*
WM. G. CROSBY, *Sec.-Treas.*
Water Pollution Control Authority
Wade Hampton Bldg., Columbia, S. C.

(Sweden) Föreningen För Vattenhygien
ERIK JONSSON, *Secretary*
Box 5038, Stockholm 5, Sweden

(Switzerland) Verband Schweizerischer Abwasserfachleute
G. KISSELEFF, *Secretary*
Limbergstr. 16, Kusnacht
Zurich, Switzerland

Texas Water and Sewage Works Assn.*
V. M. EHLERS, *Sec.-Treas.*
2202 Indian Trail, Austin, Tex.

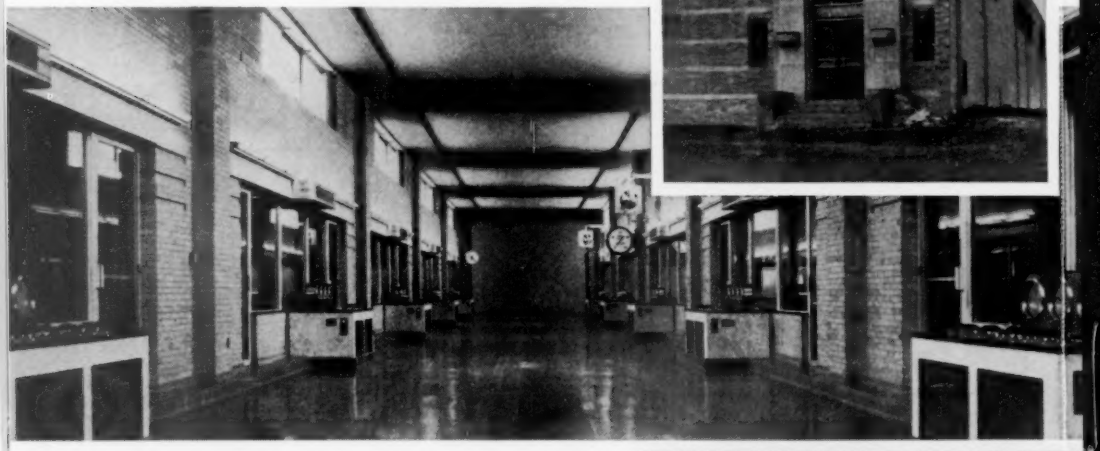
Virginia Industrial Wastes and Sewage Works Assn.
ORVAL J. HAND, *Sec.-Treas.*
Hercules Powder Co.
Hopewell, Va.

West Virginia Sewage and Industrial Wastes Assn.
GLEN O. FORTNEY, *Sec.-Treas.*
State Dept. of Health, Charleston 5, W. Va.

* Sewage and Industrial Wastes Section.

For new 40 mgd addition to Toledo's Collins Park Filtration Plant...

CONS. ENG.—Finkbeiner, Pettis & Strout; COMM. WATER—Sol J. Wittenberg
CHIEF ENG. DIV.—George Van Dorp



34 years' accurate control makes it 100% Simplex again!

34 years of accuracy. No troubles. That's the service record of Simplex filter controllers, venturi tubes and meters at Toledo.

Dependable accuracy like this is essential to your plant, too. So take a closer look at Toledo's experience with Simplex:

1921 – 34 Simplex Controllers installed.

1929 – 22 Simplex Controllers added. (All 56 coordinated with Simplex Master Control System, including Gauges & Meters.)

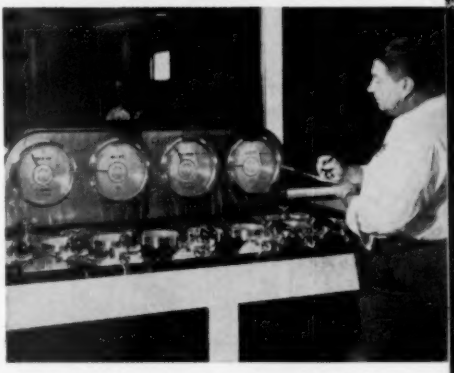
1941 – New Collins Park Plant selects: 40 Simplex Rate Controllers. (Also Simplex W. W. controllers; 60" Venturi Tubes & Meters; plus Gauges & Meters.)

And again in 1956 for Toledo's expansion to 120 mgd – it's 100% Simplex with integrated Pneumatic Master Control. Equipment chosen: 20 Rate Controllers; 60" Venturi Tubes and Meters; Gauges; Wash Water Controllers.

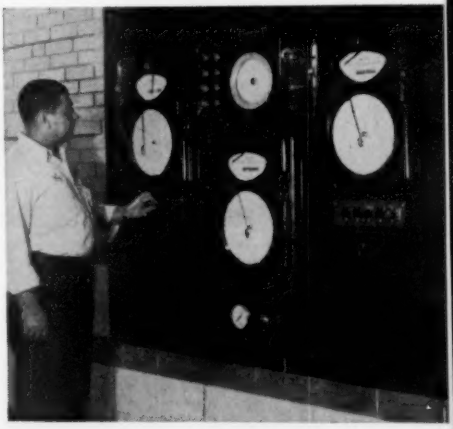
Efficient performance – with minimum maintenance – saves money throughout the years. That's why it's wisest for budget-conscious communities to start with the best.

Write for Technical Bulletins – Simplex Valve & Meter Co., Dept. SI-10, 7 E. Orange St., Lancaster, Pa.

SIMPLEX®
VALVE AND METER COMPANY
VENTURI TUBES • FLUMES • METERS • GAUGES
TRANSMITTERS • CONTROLLERS • TABLES • AIR VALVES



Compact group of easy-to-read Simplex gauges indicates rate and head loss for a pair of the 20 new 4-mgd each filter units



Part of the Simplex Pneumatic Master Control System that permits varying the rate of ten new filters from one location. This panel indicates, summates and records flow of raw, wash and filtered water

MEMBER ASSOCIATION MEETINGS

THIRTIETH ANNUAL MEETING

Federation of Sewage and Industrial Wastes Associations
in conjunction with
New England Sewage and Industrial Wastes Association
Statler Hotel, Boston, Massachusetts
October 7–10, 1957

Association	*Place*	*Time*
West Virginia Sewage and Industrial Wastes Assn.	Hotel McClure Wheeling, W. Va.	Oct. 24–25, 1957
Pacific Northwest Sewage and Industrial Wastes Assn.	Franklin Hotel Seattle, Wash.	Oct. 24–26, 1957
Canadian Inst. on Sewage and Sanitation	King Edward Hotel Toronto, Ont., Can.	Oct. 28–30, 1957
Nebraska Sewage and Industrial Wastes Assn.	Clark Hotel Hastings, Nebr.	Nov. 7–8, 1957
North Carolina Sewage and Industrial Waste Assn.	Sir Walter Hotel Raleigh, N. C.	Nov. 11–13, 1957
Florida Sewage and Industrial Wastes Assn.	Roosevelt Hotel Jacksonville, Fla.	Nov. 11–13, 1957
South Carolina Water and Sewage Works Assn.	Hotel Jefferson Columbia, S. C.	Nov. 15, 1957
Oklahoma Water, Sewage and Industrial Wastes Conf.	A. & M. College Stillwater, Okla.	Nov. 18–22, 1957

B.O.D. removal in half the space and half the time!

The PROBLEM: To provide 80% B.O.D. removal from domestic sewage and milk plant wastes combined as follows:

	G.P.D	POP. EQUIV.	B.O.D. lbs.
Domestic sewage	278,000	3132	522
Milk plant #1	24,400	2658	443
Milk plant #2	39,800	2052	342
	342,200	7842	1307

The SOLUTION: The "BIOSORPTION" activated sludge plant illustrated above was installed for maximum capacity in minimum space — highest efficiency at lowest cost. Equipment includes a CYCLATOR® clarifier combining mixing and clarification in a *single* basin; Stabilizer with 120 COLAFLEX® diffusers; GRIDUCTOR® comminutor, and digester.

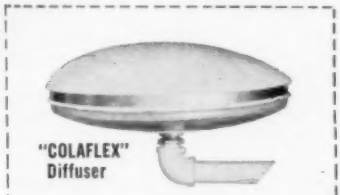
The RESULTS: Typical hourly samples composited for analysis:

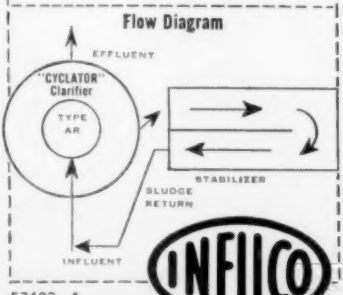
1956 Date	Time	Ave. Flow M.G.D.	B.O.D. Raw Sewage P.P.M.	B.O.D. Per-cent Re-moval	Sus. Solids Raw Sewage P.P.M.	Sus. Solids Per-cent Re-moval
Nov. 21	9 A.M.-4 P.M.	0.262	1330	80.9	—	—
Nov. 27	8 A.M.-4 P.M.	0.226	741	83.7	366	78.2
Nov. 28	8 A.M.-4 P.M.	0.248	794	88.4	480	83.3
Dec. 3	8 A.M.-4 P.M.	0.232	642	80.5	508	84.2

If your problem involves greater capacity in *less* time — from *less* space — *at lower cost* — consult INFILCO because INFILCO KNOWS HOW to help you solve it. Write today for full information on this installation and Bulletin No. 6550.

Inquiries and samples are invited on all water, sewage and waste treatment problems.

Efficient, **high-rate** "BIOSORPTION" plant installed at Neillsville. Consulting Engineers — Davy Engineering Co., La Crosse, Wis.





57423—A

INFILCO

INFILCO
INCORPORATED
General Offices • Tucson, Arizona • P.O. Box 5033
Field offices throughout the United States
and in foreign countries

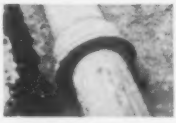
THE ONLY COMPANY impartially offering equipment for ALL types of water and waste conditioning—coagulation, precipitation, sedimentation, flotation, filtration, ion exchange and biological treatment.

"DON'T DRINK THAT!"

It's poison!
Polluted water not only endangers your life . . . it costs you money as well. Local pollution compels many communities to travel too far for drinkable water . . . and taxes climb.
If industry, our second greatest user, must purify water *before* using it, production costs soar. You pay more for goods.
Pollution robs you of your fun too . . . ruins fishing, swimming, boating.
Water officials ask your help in preventing pollution and solving other problems.

1. Encourage future water planning.
2. Support realistic water rates and water supply bond issues.
3. Conserve water where you can.

Water today is everyone's business!



PROOF POSITIVE
CAST IRON PIPE SAVES
YOU TAX DOLLARS

This cast iron water main laid in Richmond in 1833 is still in excellent condition. Such performance is typical of many century old cast iron water and gas mains still serving throughout America.

Small wonder that where long life, dependability and economy are "musts," water officials prefer cast iron pipe . . . No. 1 Tax Saver!

CAST IRON PIPE
RESEARCH ASSOCIATION — SUITE 3440, PRUDENTIAL PLAZA, CHICAGO 1, ILL.

MODERNIZED cast iron

POLLUTION IS ONLY ONE OF YOUR PROBLEMS

Your biggest problem today, probably, is to make the public aware there *is* a water problem.

Advertisements like the one at the left . . . one of our continuing campaign on conservation* . . . do exactly that.

Not only do they dramatize our current water crisis; they stress the need for public cooperation and support for all water programs.

That continuing education makes your job easier.

CAST IRON

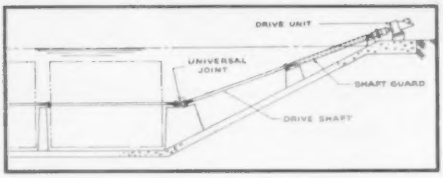
Cast Iron Pipe Research Association, Thos. F. Wolfe, Managing Director, Suite 3440, Prudential Plaza, Chicago 1, Ill.

**Appearing in:* Saturday Evening Post, Newsweek, U. S. News and World Report, Nation's Business.

pipe FOR MODERN WATER WORKS

unique FLOCTROL® drive
...new **JEFFREY** design cuts costs 3 ways

Three Jeffrey FLOCTROLS at St. Louis County Water Treatment Plant, St Louis, Missouri, employ unique parallel-to-inclined-sidewall drive arrangement.



Jeffrey sanitary engineers designed the unique FLOCTROL drive shown above. Shaft runs parallel to the inclined sidewall of clarification basin and underwater universal joint is coupled to the horizontal FLOCTROL shaft. Drive shaft is protected at water surface by a steel guard which prevents fouling due to ice formation.

This efficient new Jeffrey FLOCTROL drive affords 3-way savings:

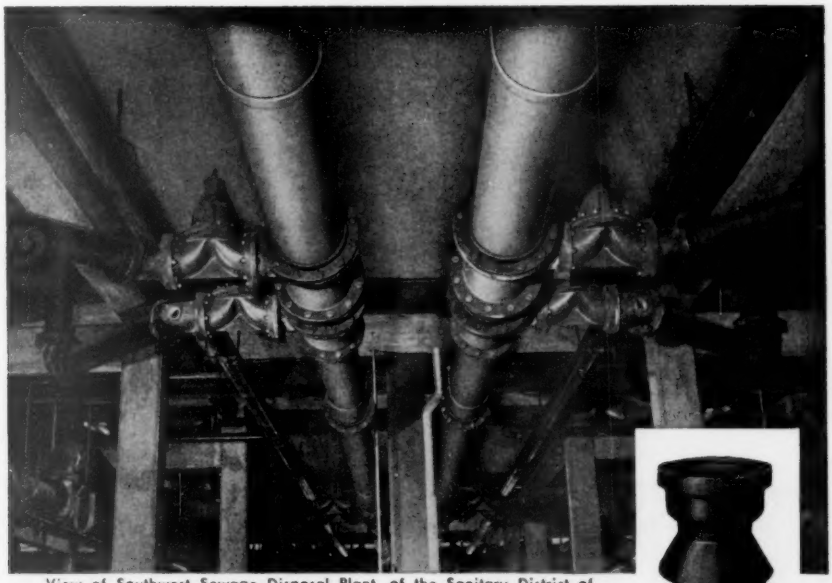
It is less expensive than drives of conventional design • Eliminates costly concrete and steel superstructures • Eliminates undesirable sprocket and chain drive through water.

Jeffrey FLOCTROLS are available in horizontal and vertical types. Horizontal units are usually installed in large plants, vertical units in smaller plants. FLOCTROL Systems eliminate short circuiting through the basin . . . provide tapered mixing for fast floc formation . . permit 30% smaller basins than are customarily required.

For details on all Jeffrey equipment for water, sewage and industrial waste treatment, write for Catalog 905. The Jeffrey Manufacturing Company, 902 North Fourth St., Columbus 16, Ohio.

CONVEYING • PROCESSING • MINING EQUIPMENT...
TRANSMISSION MACHINERY...CONTRACT MANUFACTURING

JEFFREY



View of Southwest Sewage Disposal Plant, of the Sanitary District of Chicago, Stickney, Illinois . . where Clow Cast Iron Pipe was furnished to meet exact requirements.

Clow cast iron pipe, fittings, valves and specials for sewage plant replacements or new installations

• James B. Clow & Sons with their many years of experience as manufacturers of Cast Iron Pipe and Special Castings for Filtration and Sewage Disposal Plants know the difficult piping problems that continually face the sanitary engineer. Clow shops are completely equipped with the latest machinery. Clow's skilled workmen will produce pipe and specials to your exact specifications. Pipe can be furnished flange and flange, flange and bell, flange and plain end or with mechanical joint and plain end—in sizes 3 through 24 inches in laying lengths up to 18 feet.

CLOW (Threaded) Cast Iron Pipe

Clow also manufactures (threaded) Cast Iron Pipe in steel pipe sizes 3 through 10 inches which has the same outside diameter as common steel pipe. This pipe can be cut, threaded and fitted on the job with ordinary tools of the piping trade.

JAMES B. CLOW & SONS ☆
201-299 North Talman Avenue • Chicago 80, Illinois

Subsidiaries:
Eddy Valve Co., Waterford, N. Y.
Iowa Valve Co., Oskaloosa, Iowa

INERTOL PAINTS PROTECT
MULTI-MILLION-DOLLAR MIAMI PLANT

Partial view of new Sewage Treatment Plant, City of Miami, Florida . . . buildings, tanks, equipment . . . protected with Inertol Paints.

On Virginia Key, three miles off the Florida mainland, stands Miami's new $10-million sewage treatment plant, heart of the new $27-million sewerage system. To protect this costly installation against the ravages of corrosion, fumes, condensation, salt air, heat and humidity, rugged Inertol coatings were specified (Consulting Engineers: Metcalf and Eddy, Boston, Massachusetts).

Buildings, the four 105′-diameter digesters, the towering chimney structure and other surfaces are protected economically and efficiently with *Ramuc® Masonry Paint*. Thousands more square feet of area of this 47-MGD plant are guarded with other corrosion-resistant, attractive Inertol coatings.

Buy Inertol paints direct from the manufacturer. Shipment within three days from our plant, or from nearby warehouse stocks. Write for free booklet S-754, "Principal Types of Protective Coatings."

SPECIFICATIONS FOR RAMUC MASONRY PAINT

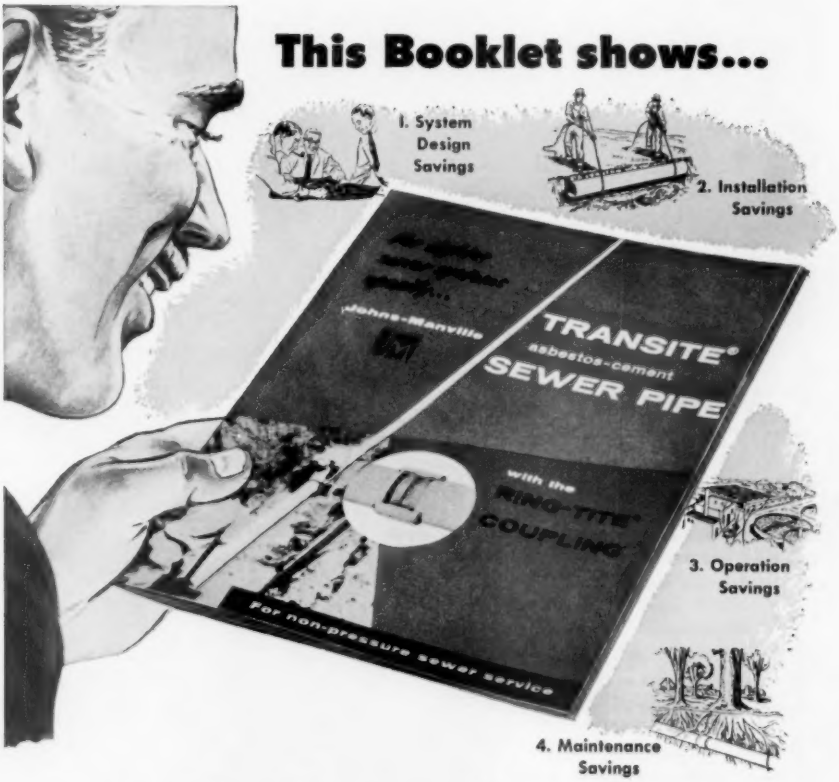
A chlorinated natural rubber-base paint in color. Flat finish. For exterior above-grade masonry. Unaffected by masonry lime. Highly weather- and fume-resistant. No mottling.

Colors: Color Chart 563.
No. of coats: Two (if semi-gloss finish desired, specify semi-gloss type for top coat).
Coverage: 150-250 sq. ft. per gal. per coat, depending on surface texture.
Approx. mil thickness per coat: 1.5.
Drying Time: 24 hours.
Primer: None. However, to minimize efflorescence, specify one coat of Pluvol* as primer.
Thinners: Inertol Thinner 2000-A for brushing; 2000, for spraying.
Application: Brushing: As furnished. Spraying: First coat must be brushed. For spraying, add sufficient Thinner 2000 (10-15%).

Inertol®

*Registered Trademark. *Write for information on Pluvol, invisible silicone water-repellent.*
A complete line of quality coatings for sewage, industrial wastes and water plants.

INERTOL CO., INC.
482 Frelinghuysen Ave., Newark 12, N. J. • 27-H South Park, San Francisco 7, Calif.



...how Transite Sewer Pipe saves in **4** important ways

Selecting the right pipe material for a new sewage system—or for additions to an existing one—is a problem of major importance to *all* concerned in influencing a choice. *And* it can be solved to *the complete satisfaction of both installer and user* with economies in each of these stages—(1) system design (2) installation (3) operation and (4) maintenance.

Engineers thinking in long-range terms of thoroughly proved sewer main performance . . . contractors interested in serving community needs at new lows in installed cost—both should know Transite® asbestos-cement Pipe and Ring-Tite® Coupling. Here is a new booklet that tells how Transite Pipe reduces infiltration, keeps out roots; maintains high flow capacity; speeds installation; permits designing the system for savings. Write for Booklet TR-165A, Johns-Manville, Box 14, New York 16, N. Y.; In Canada, Port Credit, Ont.

Johns-Manville TRANSITE SEWER PIPE

WITH THE **RING-TITE** COUPLING

Nichols Herreshoff
MULTIPLE HEARTH
Sludge • Grits • Screenings and Grease Furnace

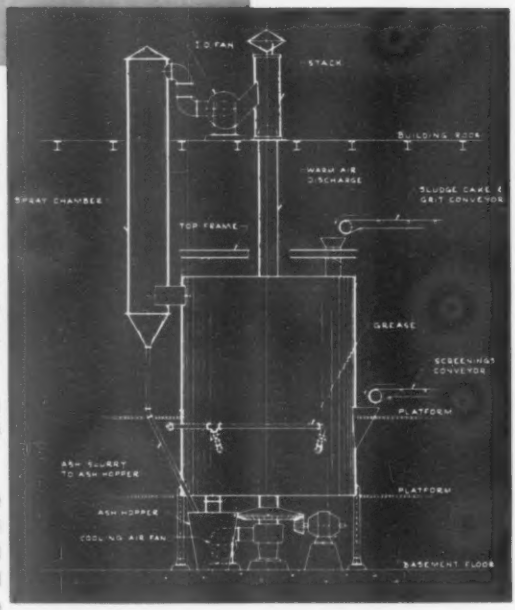
Rugged
Dependable
Economical

Sludge is not the only material posing a disposal problem at a sewage treatment plant. Grits, grease and screenings may, and frequently do, create a problem far more serious and difficult.

All sewage solids can be easily disposed of in a Nichols Herreshoff furnace, simultaneously, singly, safely, swiftly, surely and simply.

Clean? Absolutely! Odors? Never! Not from a modern Nichols Herreshoff furnace.

The secret of sewage treatment plants being "good neighbors" is good housekeeping and odorless disposal of the sludge, grit, screenings and grease in Nichols Herreshoff multiple hearth furnaces.



Schematic drawing illustrating the utter simplicity of destroying all sewage organics in a Nichols Herreshoff furnace.

Nichols Engineering & Research Corp.
70 PINE ST., NEW YORK 5, N. Y.
1637 N. Illinois St., Indianapolis 2, Ind.
1477 Sherbrooke St. W., Montreal 25, Canada

Compare them all—
You'll choose
NICHOLS HERRESHOFF

for pumping domestic and industrial wastes...

This Shone ejector has been in operation for 68 trouble-free years—in the Auditorium Hotel (Roosevelt College), Chicago, Illinois.

YEOMANS pneumatic ejectors cut service costs because

THERE'S NOTHING TO WEAR OUT

- NO ROTATING PUMP PARTS
- NO AIRTIGHT FLOATS
- NO HIGH-SPEED SHAFTS OR BEARINGS

With Yeomans pneumatic ejectors, maintenance costs are 50% to 75% lower than with the best centrifugal pumps. The secret? Simplicity of design. Yeomans pneumatic ejectors are built to give you decades of trouble-free service—in fact, they will outlast your system.

They're recommended for low gallonages. Even the smallest Yeomans ejector will pass solids up to the size of the inlet and discharge valves . . . minimum of four inches. No danger of clogging.

They're safer, and completely sanitary. Fully enclosed, hermetically sealed. Dangerous hydrogen sulphide gas is never released.

Yeomans manufactures both centrifugal pumps and pneumatic ejectors, but recommends the ejector where extreme dependability is required. Among the seven models and more than 100 sizes there is a pneumatic ejector that will exactly fill your needs.

Manufacturers of: pumps for drainage • sewage • condensation return • water supply and circulation • equipment for treatment of domestic and industrial wastes.

YEOMANS

YEOMANS, 1999-1 N. Ruby Street, Melrose Park, Illinois

simplicity

"IT'S SHORE WONDERFUL . . . EVEN COUSIN FOOLEY KIN PUT IT TOGETHER."

U.S. PIPE FOR WATER, SEWERAGE AND

itself

Our new "Tyton Joint" pipe assembles so easily even an inexperienced crew can master the technique quickly.

Only one accessory needed...a specially designed rubber gasket which seats in the bell. The entering pipe slides into place easily, compressing the gasket... making a tight, permanent seal.

No bell holes needed. What's more, "Tyton Joint" doesn't mind wet feet. You can lay it in the rain if need be!

Like to know more about this revolutionary, new pipe joint that saves time and trouble in the trench...and money on your contract?

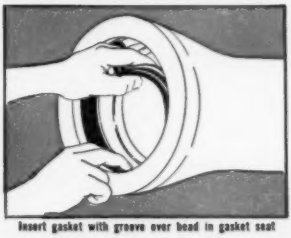
Write or call today for the facts on "Tyton."

U. S. PIPE AND FOUNDRY COMPANY
General Office: Birmingham 2, Alabama

A WHOLLY INTEGRATED PRODUCER FROM MINES AND BLAST FURNACES TO FINISHED PIPE

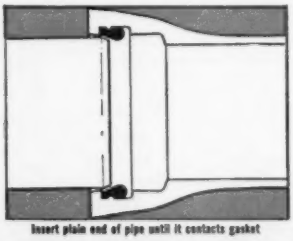
U. S. TYTON JOINT

ONLY FOUR SIMPLE ACTIONS

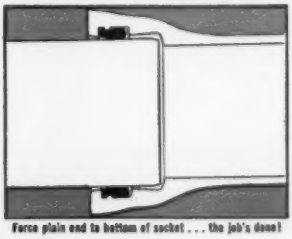


Insert gasket with groove over bead in gasket seat

Wipe a film of special lubricant over inside of gasket



Insert plain end of pipe until it contacts gasket



Force plain end to bottom of socket . . . the job's done!

AND INDUSTRIAL SERVICE

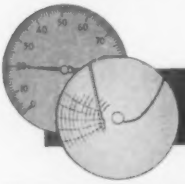
CAST IRON

When it's B/M "Matched Metering"

—you know it's accurate!

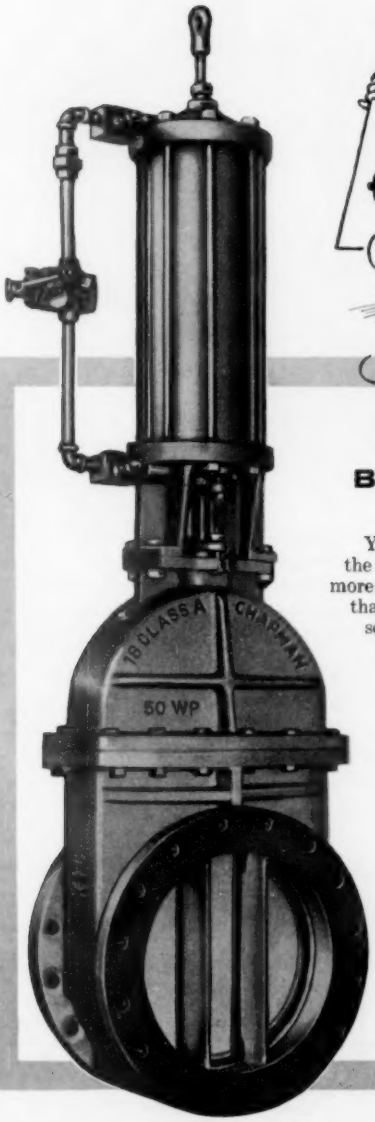
The high fidelity of Burgess-Manning Electric and Electronic Meters is made possible only by the Burgess-Manning null-balance inductance bridge, servo-powered meter principle employed. To this has been added the refinement of a calibrated cam, which matches the calibration of the recorder-totalizer and the differential producer for perfection thru "Matched Metering". Burgess-Manning electric transmission is suitable for distances up to 5000 feet. You'll never regret having specified Burgess-Manning "Matched Metering" for greatest overall accuracy. Request Catalog 800.

Burgess-Manning Meters are also available in mechanical types.



BURGESS-MANNING COMPANY
PENN INSTRUMENTS DIVISION
4122 Haverford Ave., Philadelphia 4, Pennsylvania

Instrumentation and Controls for water, steam, gases, sewage and industrial wastes



Specify

CHAPMAN

Beamed Waterway Gate Valve

You get more bearing contact area. In the partly opened position, 6 to 10 times more bearing contact area with a Chapman than with any other double disc parallel seat or square bottom gate valve. You get long wearing bearing surfaces on the beams and downstream discs. You get smooth operation, tight seats and practically no leakage.

All this is yours for less . . . less trouble, less maintenance, less time out for repairs . . . even for decades of rugged service.

For filtration plants, wash water valve service or other places for limited throttling requirements, always specify Chapman Beamed Waterway Gate Valves. You get more for less. All standard sizes . . . any desired method of operation . . . are available. Write for our Catalog No. 45 today.

The CHAPMAN Valve Manufacturing Co.

INDIAN ORCHARD, MASSACHUSETTS

"Out of sight–out of mind" can be a mighty expensive philosophy in any water distribution system. The above unretouched photograph proves this point. It shows a badly tuberculated *eight inch* main whose *inside diameter was reduced to an average of almost 4.5 inches.* Resultant higher pumping costs with reduced pressure and carrying capacity make it costly to tolerate such conditions. That is why the savings effected in reduced pumping costs frequently pay for the *low cost* of National water main cleaning.

Since there's never a charge or obligation to inspect your mains, *call National now!*

Call in National today!

NATIONAL WATER MAIN CLEANING COMPANY

50 Church Street • New York, N. Y.

ATLANTA 3, GA., 333 Candler Building • BERKELEY, CALIF., 920 Grayson Street • BOSTON 15, MASS., 115 Peterboro Street • CHARLOTTE, N. C., 533 Hollis Road • CHICAGO, ILL., 8 So. Dearborn Street • DECATUR, GA., P. O. Box 385 • EL MONTE, CALIF., 2024 Merced Avenue • FLANDEAU, S. D., 315 N. Crescent Street • KANSAS CITY, MO., 3707 Madison Avenue • MINNEAPOLIS, MINN., 200 Lumber Exchange Building • RICHMOND 21, VA., 2910 W. Clay Street • SALT LAKE CITY, UTAH, 502 West 3rd Street • SIGNAL MOUNTAIN, TENN., 204 Slayton Street • VILLA PARK, ILL., 424 S. Yale Avenue • MONTREAL, CANADA, 7445 Chester Avenue • WINNIPEG, MANITOBA, 576 Wall Street • BOGOTA, COLOMBIA, Apartado de Correos #5 • SAN JUAN 10, PUERTO RICO, Manquinaria, Apartado 2184 • LIMA, PERU, Bolivar 441-A, Marafi • CARACAS, VENEZUELA, Apartado 561 • OSLO, NORWAY, Radhusgaten 30

Test after test, made by various independent research organizations, conclusively prove that DURAJOINT Waterstops are the only waterstops available on which you can stake the safety of your design and reputation. The results of these tests plus the many other advantages offered by DURAJOINT Waterstops are concisely stated in our new Waterstop Manual No. 457. Check and mail the coupon below for your free copy . . . it will make an excellent addition to your waterstop file.

DURAJOINT TECHNICAL INFORMATION *Center*
121 HILL AVENUE • AURORA, ILLINOIS

Gentlemen:

DEPT. 36

☐ Please send me, without obligation, a copy of Manual No. 457.

☐ Have Representative call.

NAME_____

FIRM_____

ADDRESS_____

CITY_____ STATE_____

Proved most effective sanitation chemical in all types of applications

CLOROBEN

provides fast, sure treatment of sewage, controls odor!

Specify and use CLOROBEN for up-sewer treatment to control odor, minimize corrosion, improve plant operation.

Specify and use CLOROBEN for septic tanks cesspools, chemical toilets.

CLOROBEN! Unquestionably the choice of professional sanitation engineers.

ON REQUEST: Technical Brochure describing **CLOROBEN** applications and performance data.

CLOROBEN CHEMICAL CORPORATION

115 Jacobus Avenue,
South Kearny, New Jersey

Affiliate of: { Standard Chlorine Chemical Co., Inc.
{ Standard Naphthalene Products Co., Inc.

SAVE THE LABOR COSTS OF TWO MEN IN THE TRENCH!

Specify Concrete Pressure Pipe for your city's next job and slash installation costs as much as 50 per cent! Easy-fitting rubber gasket joints are extremely simple to join. On many installation jobs, work formerly requiring 5 and 6-man crews can now be done by 2 or 3 men.

To save money for your city—all along the line—specify Concrete Pressure Pipe and get these "4 big savings" built into every piece of Concrete Pressure Pipe.

1. YOU SAVE ON FIRST COSTS—The variety of designs available in Concrete Pressure Pipe makes it possible to choose the most economical design which will serve with maximum efficiency under the specified operating conditions required of the line.
2. YOU SAVE ON INSTALLATION COSTS—With rubber gasket joints, no caulking, bolting or welding is required. You can have minimum width trenches and immediate backfilling.
3. YOU SAVE ON MAINTENANCE COSTS—Durable Concrete Pressure Pipe has an experience record of almost complete freedom from corrosion and tuberculation. Elastic design virtually eliminates possibility of bursting—even under conditions of extreme surge and water hammer.
4. YOU SAVE ON OPERATING COSTS—Freedom from tuberculation insures a high sustained carrying capacity. No spiralling pumping costs and no reduced pressures.

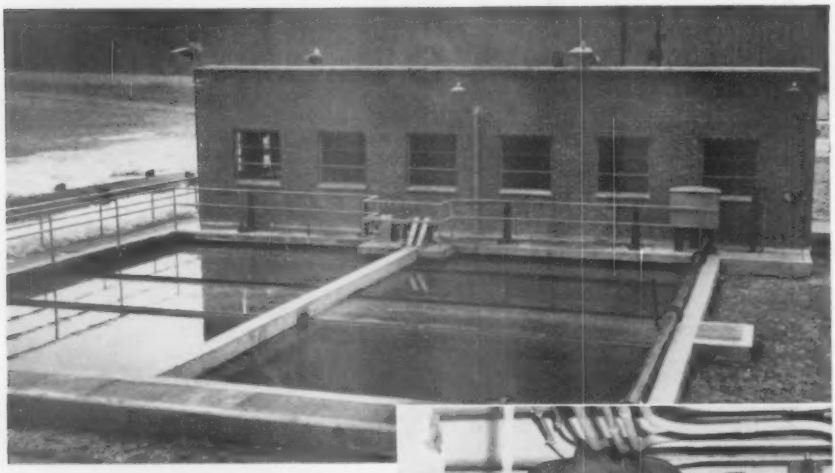
In the main—the trend is to concrete!

AMERICAN CONCRETE PRESSURE PIPE ASSOCIATION

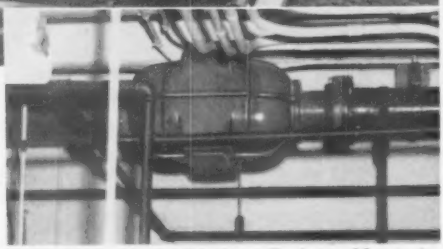
228 North LaSalle Street • Chicago 1, Illinois

City of Sidney, Ohio gets . . .

Smooth Measurement of Sludge Magnetically



with FOXBORO MAGNETIC FLOW METER

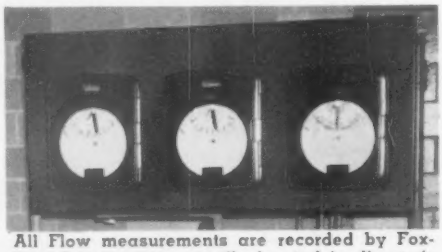


This compact, trouble-free Foxboro Magnetic Flow Meter is installed right in the return activated sludge line at Sidney, Ohio's modern new sewage plant. There's nothing in the line to obstruct flow . . . no pressure taps or purges.

No line restrictions — no pressure taps. With the Foxboro Magnetic Flow Meter there's nothing in the line to cause pile-up of solids. And you can forget about purging of pressure taps — there aren't any. Electric cable carries measurement signal to remote Dynalog* Electronic Recorder, providing a direct magnetic measurement of fluid velocity.

Get full details on this unique development in flow meters. Write for Bulletin 20-14B. **The Foxboro Company, 8910 Neponset Ave., Foxboro, Mass., U. S. A.**

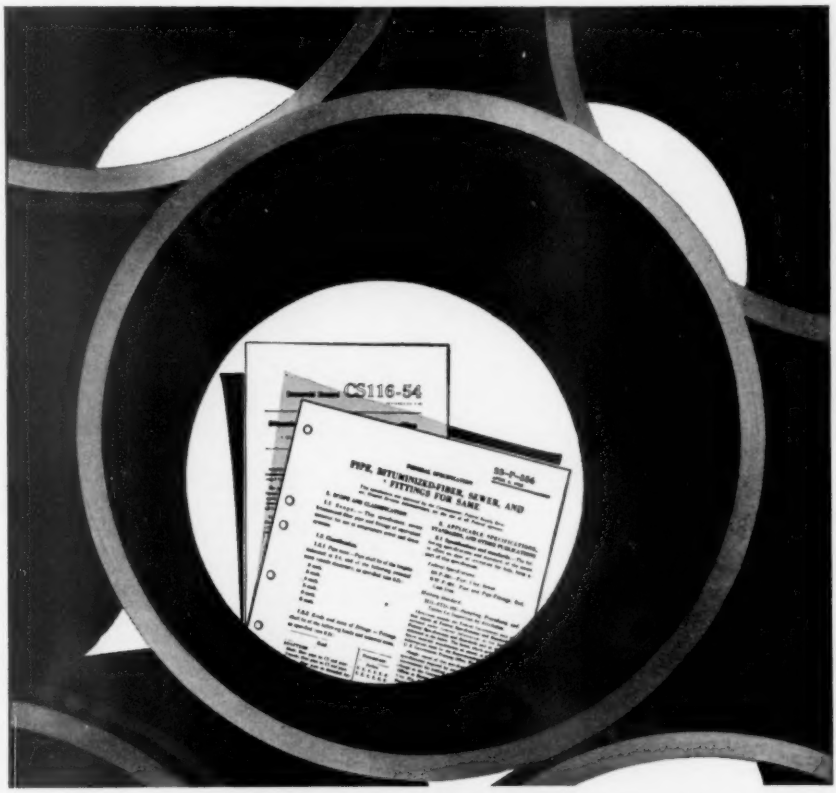
*Reg. U.S. Pat. Off.



All Flow measurements are recorded by Foxboro Instruments centrally located in director's office at Sidney plant. Shown above are: (l. to r.) Air Flow Recorder with integrator; Sewage Flow Recorder with integrator; Dynalog Recorder for return activated sludge.

FOXBORO *FIRST in FLOW*

Reg. U.S. Pat. Off.



Get to know BERMICO®

Even as plumbing codes are being tightened up, more and more code authorities are approving BERMICO Sewer Pipe, the root-proof, long lasting, easy-to-install pipe for house-to-sewer or septic tank connections.

The Southern Building Code Congress of States from Virginia to Texas, and the W.P.O.A. with members in all Pacific Coast States, have approved it. So have San Diego and nearly a dozen other counties in California, as well as counties in many other states. In Salt Lake City, Oakland, Los Angeles, Portland, Oregon; Detroit, Milwaukee, Denver, Atlanta, Cleveland, Jacksonville, to name a few, city ordinances authorize its use.

Made of tough cellulose fibre impregnated with coal-tar pitch, Bermico insures dependable connections with sewer lines. Light weight, resilient 8-foot lengths can be installed rapidly, joined instantly without sealing compound. BERMICO exceeds Federal Specifications SS-P-356 . . . and Commercial Standard CS116-54.

Your community's interests will be well served by a modernized plumbing code that includes BERMICO. Write for complete data, Dept. BJ-10, our Boston office.

BROWN QUALITY COMPANY

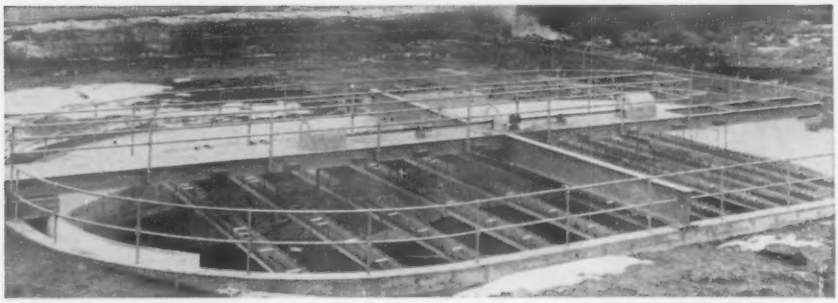
General Sales Offices:
150 Causeway Street, Boston 14, Mass.

Mills:
Berlin, New Hampshire and Corvallis, Ore.

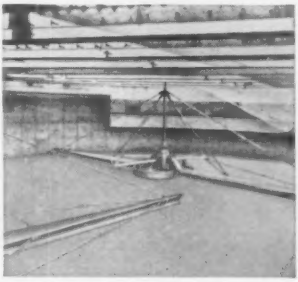
REX®

UNITUBE TOW-BRO®

chosen to solve a difficult sludge removal problem



Construction view of unique settling tank at Wilson & Co. waste treatment plant, Albert Lea, Minn. This new high-rate anaerobic digestion process for treating packing plant waste was developed jointly by W. J. Fullen of Austin, Minn., and Professor G. J. Schroepfer, University of Minnesota. Plant was designed by A. J. Steffen, Wilson & Co. Sanitary Engineer, and the Consulting Engineering firm of Toltz, King, Duvall, Anderson and Associates, Inc.



Close-up of Unitube headers.

THE PROBLEM: Wilson & Co. at Albert Lea, Minnesota, needed an efficient treatment plant for handling packing plant waste. Pilot plant work and investigation by consulting engineers and Mr. Steffen indicated the need for a sludge removal device to meet these rigid requirements:

1. Complete removal of sludge from tank bottom for each revolution of sludge removal device (8½ min.)
2. Ability to handle tremendous sludge volumes (up to 300% of raw flow)
3. High solids concentration
4. Flexibility
5. Proven hydraulic design
6. Provisions for single- or two-stage operation

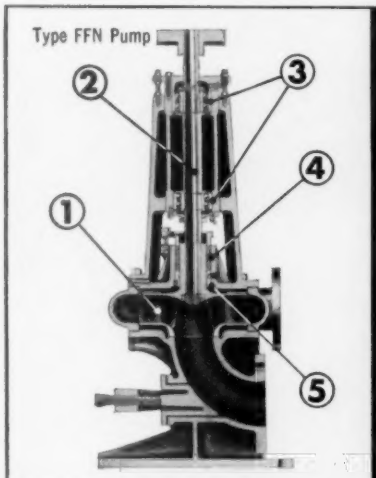
CHAIN Belt's broad experience in the hydraulics of settling basins and in the application of Tow-Bro was called upon in working out a solution to the problem.

THE SOLUTION: The Rex Unitube Tow-Bro mechanisms with interchangeable headers installed in a unique dumbbell-shaped tank. A novel inlet and effluent system provides for either single- or two-stage operation in the single tank.

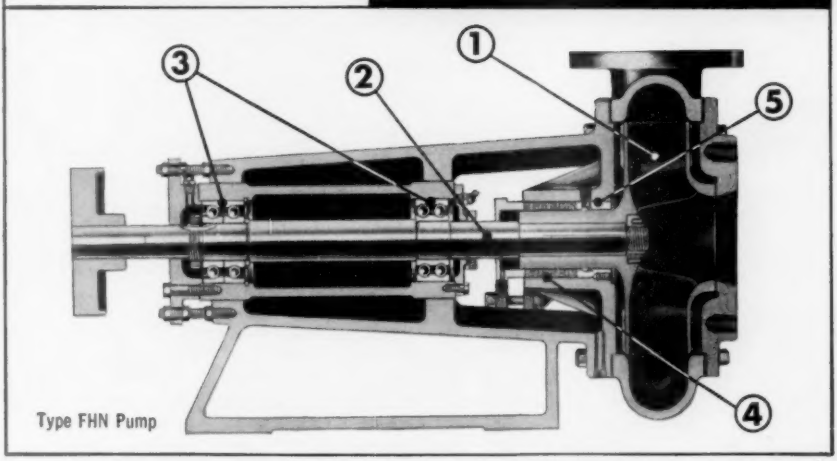
For any sludge removal problem, Unitube Tow-Bro design assures a clearer effluent... greatest solids concentration... less reaeration... greater operating flexibility... low operating and construction costs. For complete information, write for your copy of Bulletin 315-81. CHAIN Belt Company, 4606 W. Greenfield Ave., Milwaukee 1, Wisconsin.

CHAIN BELT COMPANY

Milwaukee 1, Wisconsin



The **5** features you need for **low-maintenance** pump operation



Wheeler-Economy Non-Clog Pumps are designed and built for one of the most severe types of service—that involving unscreened sewage. The five features shown here are your assurance that whether you need a horizontal or a vertical pump, you get more dependable service with Wheeler-Economy.

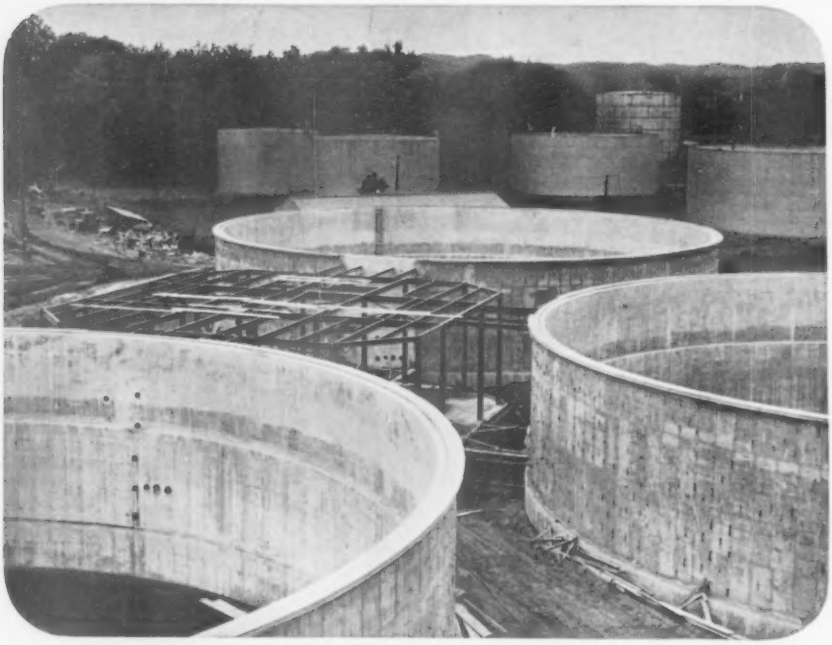
TWO NEW CATALOGS AVAILABLE! For a free copy of Catalog F-100 (describing Vertical Non-Clog Pumps), or F-101 (describing Horizontal Non-Clog Pumps), write:

Economy Pump Division
C. H. Wheeler Mfg. Co.
19th and Lehigh Avenue, Phila. 32, Pa.

1. ***Non-Clog Impeller*** *has scraper blades on back to prevent accumulation of rags, matches, other solids. Impeller nut is countersunk to eliminate clogging.*
2. ***Heat-Treated Alloy Steel Shaft*** *is oversize to provide utmost rigidity even in heavy service. Precision ground, turned and finished.*
3. ***Two Double-Row Ball Bearings*** *carry thrust and radial loads. Generously sized for long bearing life, smooth pump operation. Deep-grooved, grease-lubricated.*
4. ***Oversize Stuffing Box*** *assures long packing life. Designed to prevent water leakage. Furnished with seal ring.*
5. ***Renewable Shock Absorber*** *prevents shaft deflection, protects bearings from shock due to pumping heavy, irregular objects. When abrasives are being handled, clear-water connection prevents excessive pump wear.*

Centrifugal, Axial and Mixed Flow Pumps • Steam Condensers • Vacuum Equipment • Marine Auxiliary Machinery • Nuclear Products

Earle Vinnedge, Worthington Corp., and Lou Motz, Pumping Station Supervisor, Cincinnati Main Pumping Station, check performance of Worthington



Louisville builds its concrete sewage treatment plant *for 1977*

Shown here are views in the construction of the Louisville, Ky., $6 million concrete sewage treatment plant. It is designed for a 100 mgd flow in dry weather and a storm flow of 338 mgd. An expected 40% population increase to 570,000 in 1977 has been taken into consideration.

The plant, designed by Metcalf & Eddy, of Boston, Mass., was constructed by Gust K. Newburg Co., of Chicago, Ill.

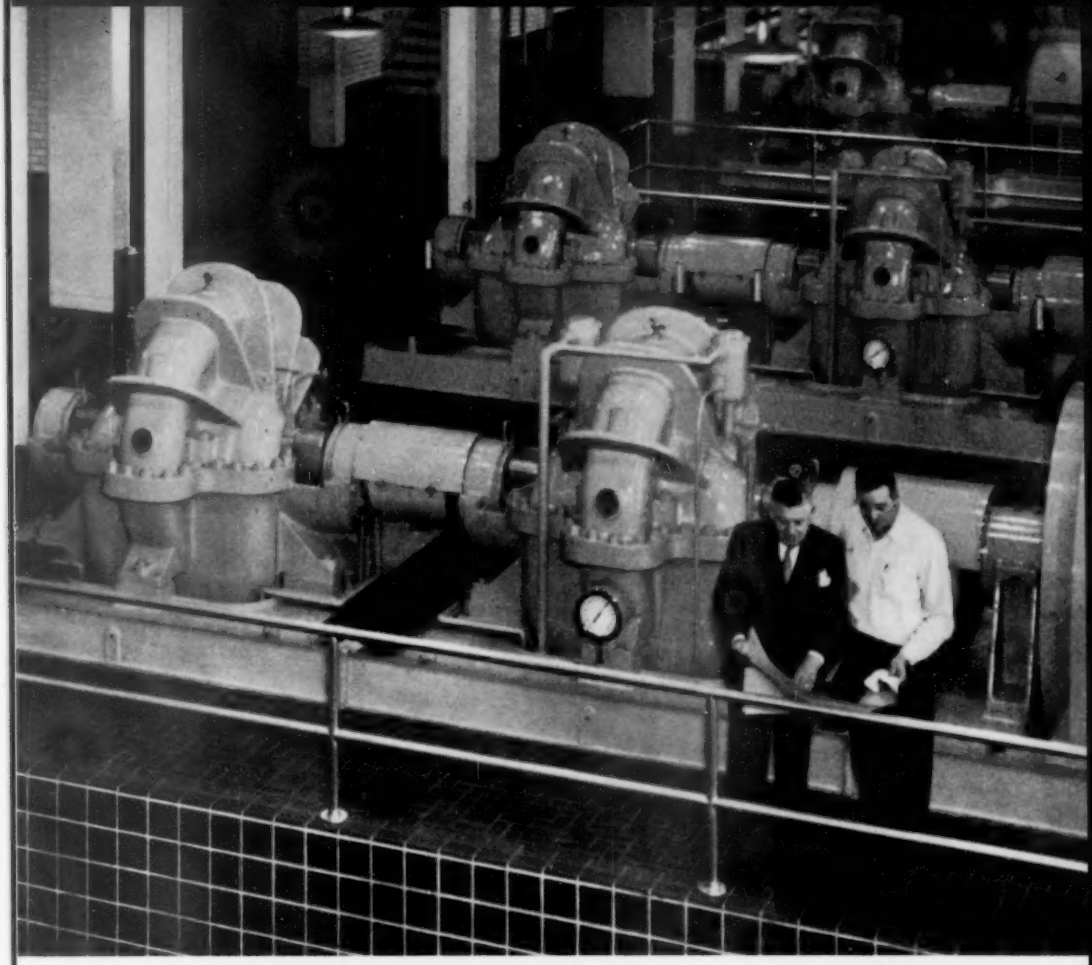
Concrete is the ideal construction material for sewage treatment plants. It offers (1) *unusual durability* to resist weathering, decay, termites and fire, (2) *great strength* and (3) *real economy* due to moderate first cost, low maintenance cost, long life and low annual cost. Ask for free booklet on financing sewage treatment works. Its distribution is limited to the United States and Canada.

PORTLAND CEMENT ASSOCIATION

Dept. A10-76, 33 West Grand Avenue, Chicago 10, Illinois

A national organization to improve and extend the uses of portland cement and concrete through scientific research and engineering field work

Earle Vinnedge, Worthington Corp., and Lou Motz, Pumping Station Supervisor, Cincinnati Main Pumping Station, check performance of Worthington pumps installed in 1957. Earle represented one contact—one responsibility for the pumping equipment. We believe you too will find it advantageous to deal with the Man from Worthington. Cincinnati Water Works. Main Pumping Station. Consultants: Black and Veatch, Kansas City, Mo.



.5 MGD TO 500 MGD

Any size, you have more to choose from with Worthington

These Freflo sewage pumps typify hundreds of Worthington equipped treatment plants.

You benefit two ways when you deal with Worthington – world's leading builder of public works equipment.

An unbiased recommendation. Because Worthington makes all types of pumps and drives and a complete line of engines, compressors, comminutors and auxiliary equipment, you get equipment recommendations based on a broad look at all ways of doing the job. You have a choice, for example, of either vertical or horizontal centrifugal pumps. In many other ways – some small, some major – the Worthington line lets you tailor the equipment to the specific requirements of your plant.

Unit responsibility. You do business with one company—eliminating delays and inconvenience that can occur when you are forced to coordinate the efforts of several suppliers. Unit responsibility by Worthington saves you time and money.

Small or large, you'll do better by consulting Worthington. For more information call your nearest Worthington District Office. Or write to Section W-71, Worthington Corporation, Harrison, N. J.

WORTHINGTON

Largest floating cover digester installation on the West Coast—
San Francisco's North Point Sludge Treatment Plant

At San Francisco, California . . .

10 P.F.T. Floating Cover Digesters installed to gain "Controlled Digestion" advantages

In operation since 1952, this modern plant has a digester capacity of 2,451,000 cubic feet, and handles sewage sludge for a population of 1,169,000. The plant was designed and equipped to effectively control action in the digestion tanks, and to efficiently utilize the large volume of solids.

There are two batteries of five digesters, and a control building for each group. All ten digesters are equipped with 100′ diameter *P.F.T. Floating Covers* for positive scum submergence and safe utilization of gas. The snug-fitting P.F.T. covers eliminate odor problems —an important consideration in this installation because of a residential area close-by. Gas collected under the domes is maintained at constant pressure under all operating conditions, greatly reducing explosion hazards. Capacity is highly flexible, because no fixed levels need be maintained; covers simply rise or lower with additions and withdrawals.

Housed in the control buildings are a total of eight *P.F.T. #1500 Digester Heaters and Heat Exchangers*, equipped with automatic controls. These heaters—using sludge gas as fuel—maintain constant digester temperatures, and also heat the control buildings. Rated heater output capacity is 12,000,000 B.t.u./Hr. Other P.F.T. equipment at this plant includes floating cover position indicators, and a full complement of *P.F.T. Gas Safety Equipment.*

Design of plant by / *Engineering office of Clyde C. Kennedy, San Francisco, Cal.*

P.F.T.

waste treatment equipment exclusively since 1893

PACIFIC FLUSH TANK CO.

4241 Ravenswood Avenue
Chicago 13, Illinois

PORT CHESTER, N. Y. • SAN MATEO, CALIF. • CHARLOTTE, N. C. • JACKSONVILLE • DENVER

SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 29 | October, 1957 | Number 10

Contents

Sewage Works

Chemical Oxygen in Biological Waste Treatment. By Ross E. McKinney and Richard A. Conway 1097

Continuing Research Related to Detergents in Water and Sewage Treatment. By H. V. Moss 1107

Settling and Compaction Characteristics of Biological Sludges. I. General Considerations. By W. Wesley Eckenfelder, Jr., and Norman Melbinger 1114

The Significance of Detention in Sedimentation. By E. B. Fitch 1123

Planned Water Reclamation. By A M Rawn and F. R. Bowerman 1134

Water Reclamation Experiments at Hyperion. By H. A. van der Goot 1139

Industrial Wastes

Activated Sludge Treatment of Kraft and Neutral Sulfite Mill Wastes. By Ben V. Pearman, Jr. and Oliver B. Burns, Jr. 1145

A Broad Picture of Industrial Waste Pollution Abatement. By Blucher A. Poole and Perry E. Miller 1155

Two-Stage Filter Operation at the Upjohn Waste Treatment Plant. By L. B. Tompkins 1161

Liquid Wastes Control at the General Electric Company Research Laboratory. By V. deP. Lukas and H. M. Ottaway 1166

An Investigation into the Disposal of Blood by Anaerobic Digestion. By Kelsie B. Singleton 1174

Stream Pollution

Characteristics of a Stream Composed of Oil Refinery and Activated Sludge Effluents. By F. J. Ludzack, Wm. Marcus Ingram, and M. B. Ettinger 1177

The Operator's Corner

Initial Digester Start-Up at Alexandria, Virginia. By S. W. Shafer 1190

Sewage Pump Bearings and Packing. By Paul Ehrenfest 1199

Proper Pump Maintenance 1203

Tips and Quips 1205

Proceedings of Member Associations

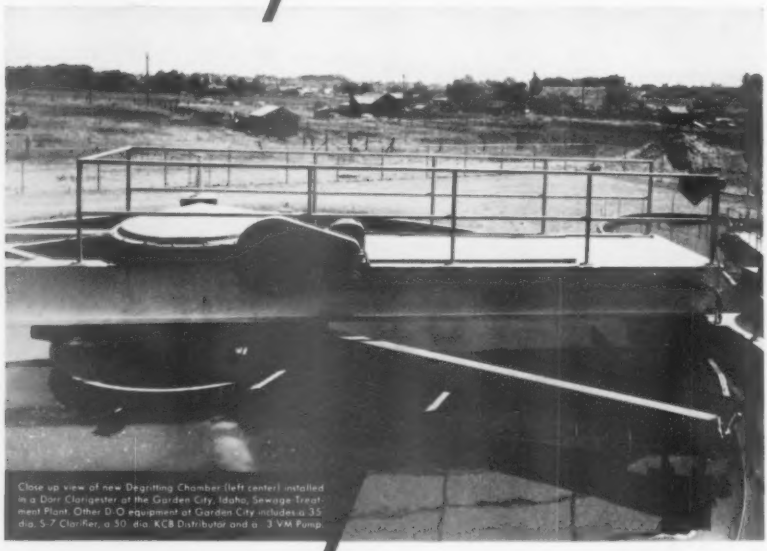
Michigan Sewage and Industrial Wastes Association 442a

Ohio Sewage and Industrial Wastes Treatment Conference 444a

Ralph E. Fuhrman, *Editor*, 4435 Wisconsin Ave., N.W., Washington 16, D. C.
Dr. F. W. Mohlman, *Advisory Editor* Donald P. Schiesswohl, *Assistant Editor*
Mrs. Elizabeth Quick, *Production Manager*

Copyright © 1957, by the Federation of Sewage and Industrial Wastes Associations. Reprints from this publication may be made only if permission of the Editor is secured and on condition that the full title of the article, name of the author and complete reference are given. The Federation assumes no responsibility for opinions or statements of facts expressed in papers or discussions published in this *Journal*.

IT'S NEW / It's from DORR-OLIVER



Close up view of new Degritting Chamber (left center) installed in a Dorr Clarigester at the Garden City, Idaho, Sewage Treatment Plant. Other D-O equipment at Garden City includes a 35' dia. S-7 Clarifier, a 50' dia. KCB Distributor and a 3 VM Pump.

A DEGRITTING CLARIFIER

A new two-in-one unit for small sewage treatment plants, the Dorr Degritting Clarifier or Clarigester combines positive mechanical degritting with conventional clarification in a single tank. Applicable for maximum flows of 0.45 to 1.75 MGD, this new design incorporates an annular chamber around the Clarifier feed well.

As Clarifier feed enters the chamber, grit settles and is removed by rakes attached to the Clarifier skimming arm. Overflow from the grit chamber discharges over a weir into the feed well. A by-pass slide gate allows discharge of the feed directly into the Clarifier when desired.

This new design is equally adaptable to both Dorr Type 'A' Clarifiers and Dorr Clarigesters. In either case, it will remove troublesome grit from the raw sewage without the need for costly, separate grit handling facilities.

For more complete information on this new two-in-one unit write Dorr-Oliver Incorporated, Barry Place, Stamford, Connecticut.

DORR-OLIVER
INCORPORATED
WORLD-WIDE RESEARCH • ENGINEERING • EQUIPMENT
STAMFORD • CONNECTICUT • U.S.A.

Sewage Works

CHEMICAL OXYGEN IN BIOLOGICAL WASTE TREATMENT *

By Ross E. McKinney and Richard A. Conway

Assistant Professor of Sanitary Engineering and Research Assistant, respectively, Massachusetts Institute of Technology, Cambridge, Mass.

The stabilization of organic matter by microorganisms in streams, lakes and biological treatment processes is brought about by a combination of two metabolic processes, oxidation and synthesis. Considerable research has been carried out as to the relationship between oxidation and synthesis in aerobic waste treatment systems; but little research has been directed toward the oxidation-synthesis relationships in anaerobic systems, or even on the mechanism of oxidation of organic matter under aerobic conditions. The purpose of this paper is to present the basic considerations in the oxidation of organic matter and their relationship to sanitary engineering problems.

Oxidation-Reduction

The biological stabilization of organic matter is brought about by a series of coupled oxidation-reduction reactions (1) in which a portion of the organic matter is utilized for energy and a portion for synthesis. The energy reactions are those in which complete stabilization of the organic matter occurs. In synthesis reactions the organic matter is merely transferred from one form to a second form; namely, bacterial protoplasm.

In biological systems there are two types of oxidation systems of interest to the sanitary engineer—aerobic oxidation and anaerobic oxidation. In aerobic oxidation dissolved oxygen is the ultimate hydrogen acceptor; in anaerobic oxidation the ultimate hydrogen acceptor can be oxidized organic matter, nitrates, nitrites, sulfates, or carbon dioxide. The basic mechanism of biological oxidation is not by the direct addition of oxygen to the organic molecule being oxidized but rather by the removal of hydrogen between adjacent atoms to create an unsaturated double bond and the subsequent addition of water. The oxidation reaction is shown in Figure 1. The adjacent atoms are normally carbon atoms, but they can be carbon-oxygen, carbon-nitrogen, or even two nitrogen atoms.

Hydrogen Transfer Enzyme System

The problem in oxidation lies in the fate of the two hydrogen atoms removed from the organic molecule and the succeeding pairs of hydrogen atoms that must be removed if complete oxidation is to occur. As in the case of all bacterial reactions, the removal of the hydrogen atoms is brought about by a special enzyme system. The predominant hydrogen transfer enzyme system utilizes diphosphopyridine nucleotide (DPN). For the purpose of simplification—in the face of oversimplification—DPN is used throughout this paper as representing all hydrogen transferring systems in the initial reaction with organic matter. In removing hydrogen from organic mat-

* Presented at the 1957 Spring Meeting, New England Sewage and Industrial Wastes Assn.; Newport, R. I.; June 6, 1957.

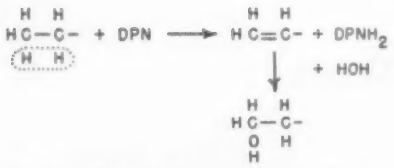


FIGURE 1.—Bacterial oxidation of organic matter.

ter the DPN becomes reduced, $DPNH_2$ or DPNH. The bacteria have only a limited amount of DPN. If the DPN were all reduced to $DPNH_2$, the oxidation reactions would cease. Therefore, it is imperative for the bacteria's own survival that a system exist whereby the $DPNH_2$ can be regenerated to DPN.

Aerobic

It is in the mechanism for regeneration of $DPNH_2$ that the differences between aerobic and anaerobic bacteria exist. The aerobic bacteria have the more complicated system of oxidation. Because the anaerobic systems are mainly modifications from the aerobic scheme, the aerobic scheme is presented first.

The $DPNH_2$ gives up its hydrogen to a flavin adenine dinucleotide, better known as FAD. Although the $DPNH_2$ is oxidized back to DPN, FAD is reduced to $FADH_2$. $FADH_2$ must also be regenerated and passes its hydrogen along to the cytochrome system. The cytochrome system is made up of several enzymes all closely related in structure and utilizing iron as the agent for transferring the hydrogen atoms from $FADH_2$ to molecular oxygen. The cytochrome systems vary among the bacteria, but this variance has no important effect on the transfer of hydrogen to oxygen. The iron in the cytochrome system exists as ferric iron and is reduced to ferrous iron by $FADH_2$. The ferrous iron is oxidized back to ferric iron by molecular oxygen, which becomes reduced to water. The over-all aerobic scheme of oxidation is shown in Figure 2.

Anaerobic

In the absence of dissolved oxygen the bacteria turn to other sources of oxygen to act as the hydrogen acceptor. The facultative bacteria have the ability to metabolize organic matter both in the presence and in the absence of dissolved oxygen. The metabolic reactions include the complete aerobic hydrogen transfer scheme shown in Figure 2 and two shunts. The primary shunt is in the cytochrome system, where nitrates take up the hydrogen and are reduced to nitrites. Some species of bacteria can carry the nitrate reduction completely to nitrogen gas. The secondary shunt exists at

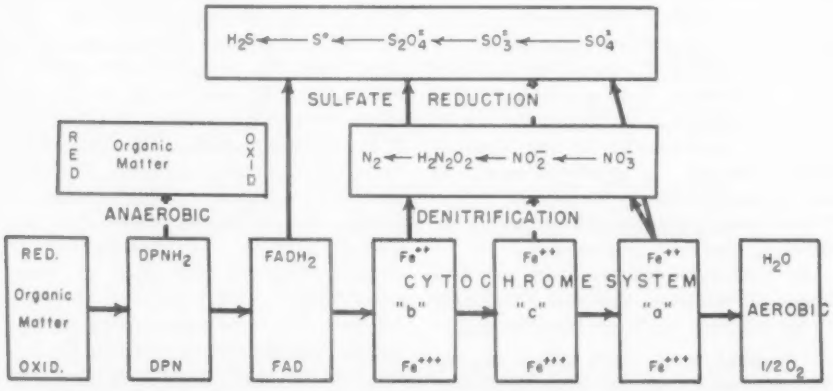


FIGURE 2.—Various mechanisms of bacterial oxidation by hydrogen transfer.

the $DPNH_2$ level, where the hydrogen atoms are transferred to a molecule of oxidized organic matter to form a molecule of reduced organic matter.

There are the obligate anaerobes, which carry out all oxidations by the DPN system. It can readily be seen that it is impossible for the obligate anaerobe to stabilize an organic solution completely. One molecule of organic matter must be reduced while another molecule is oxidized. The reduced organic matter builds up in solution and prevents complete stabilization.

Two groups of specialized anaerobic bacteria exist which can utilize the reduced organic matter produced by the facultative bacteria and by the other anaerobic bacteria. The *Desulfovibrio* have the ability to use sulfates as their hydrogen acceptor, with the production of hydrogen sulfide. The mechanism of sulfate reduction is not fully known, but has been shown to be connected with a portion of the cytochrome system. The other group of bacteria are the methane bacteria, which have the ability to reduce either carbon dioxide or the anaerobic end products of other bacteria to form methane. Nothing is known of the mechanism for transferring hydrogen to form methane.

Energy

The energy relationships for the metabolism of any organic matter determine which system of metabolism will predominate and hence what group or groups of bacteria will predominate. The energy equations for the metabolism of a simple molecule, such as acetate, are as follows (All free energy values taken from Lange's Handbook (2)):

1. *Oxygen*

$$C_2H_3O_2Na + 2O_2 \rightarrow NaHCO_3 + H_2O + CO_2 - \Delta F$$
$$-152.3 + 0 = -203.9 - 56.7 - 94.3 - \Delta F$$
$$\Delta F = -202.6 \text{ kg.-cal. per mole acetate}$$

2. *Nitrates*

$$5C_2H_3O_2Na + 8NaNO_3 \rightarrow 4N_2 + 7NaHCO_3 + 3Na_2CO_3 + 4H_2O - \Delta F$$
$$-761.5 - 712.0 = 0 - 1427.3 - 754.2 - 226.8 - \Delta F$$
$$\Delta F = -934.8 \text{ kg.-cal.}$$
$$= -187.0 \text{ kg.-cal. per mole acetate}$$

3. *Sulfates*

$$C_2H_3O_2Na + Na_2SO_4 \rightarrow 2NaHCO_3 + NaHS - \Delta F$$
$$-152.3 - 302.5 = -407.8 - 58.2^* - \Delta F$$
$$\Delta F = -11.2 \text{ kg.-cal. per mole acetate}$$

4. *No Oxygen*

(a) Acid-Alcohol

$$3C_2H_3O_2Na + 2H_2O \rightarrow 2C_2H_6O + NaHCO_3 + Na_2CO_3 - \Delta F$$
$$-456.9 - 113.4 = -83.6 - 203.9 - 251.4 - \Delta F$$
$$\Delta F = 30.4$$
$$= 10.1 \text{ kg.-cal. per mole acetate}$$

(The positive sign for ΔF indicates energy is not produced by this reaction, but is required for the reaction. Because bacteria require energy, they will not

* Estimated.

carry out this reaction even though it balances chemically. This means that acetate is a stable end product of normal anaerobic metabolism.)

(b) Methane

$$C_2H_3O_2Na + H_2O \rightarrow CH_4 + NaHCO_3 - \Delta F$$
$$-152.3 - 56.7 = -12.1 - 203.9 - \Delta F$$
$$\Delta F = -7.0 \text{ kg.-cal. per mole acetate}$$

The energy available in the oxidation of acetate is shown graphically in Figure 3. From this group it is easy to see that the general oxidation pattern for organic matter, based on hydrogen acceptors, should be as follows:

1. Dissolved oxygen.
2. Nitrates.
3. Sulfates.
4. No oxygen.

This pattern has generally been accepted in sanitary engineering, but no research has been done to determine if the theoretical considerations are valid and if chemical oxygen from nitrates and sulfates can be used to completely stabilize an organic waste. The purpose of this paper is to present data to establish the chemical oxygen relationships for biological stabilization of organic matter in waste waters.

Equipment

The laboratory study was conducted with 1.5 l. biological treatment systems. The oxygen system was supplied diffused air at 10 to 15 p.s.i. in sufficient quantities to keep the activated sludge formed in suspension. The no-oxygen units were maintained in 2-l. beakers and stirred continuously at 40 r.p.m. to keep the biological growth in suspension.

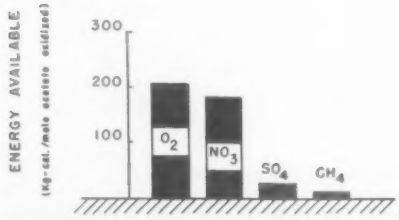


FIGURE 3.—Relative free energy available from the oxidation of acetate.

Operation Procedures

The biological units were started from an initial seed of activated sludge, 11 ml. mixed liquor of a laboratory activated sludge stabilizing acetate. The mixing period was 23 hr., followed by 1 hr. settling. One liter of supernatant was withdrawn and 1 l. of fresh substrate added. In this way the biological solids were allowed to build up without wasting.

Substrates

Two substrates were used in this study—sodium acetate and an industrial waste. Sodium acetate was chosen as the basic substrate because acetate is the key intermediate in the metabolism of all organic compounds other than the single-carbon compounds. Thus, the results obtained from acetate can be applied to all other organic substrates with proper adjustment. The sodium acetate substrate had the following formulation:

2,300 mg. $NaC_2H_3O_2 \cdot 3H_2O$
1,000 mg. KH_2PO_4
250 mg. $(NH_4)_2HPO_4$
1,000 ml. Cambridge tap water

In addition to the nutrients the nitrate unit had 3,870 mg. of $NaNO_3$ added and the sulfate unit received 4,750 mg. Na_2SO_4. The 5-day B.O.D. of the acetate waste was 760 mg. per liter, whereas the C.O.D. was 1,070 mg. per liter.

The industrial waste was a synthetic

chemicals waste containing fatty acids, alcohols, aromatics, and sulfuric acid. The waste was neutralized with sodium hydroxide to pH 7.5 and was buffered as follows:

1,000 mg. KH_2PO_4

250 mg. $(NH_4)_2HPO_4$

1,000 ml. industrial waste

The aeration unit and the nitrate unit both received the same dosage of sodium nitrate as in the acetate study. All three of the units received 2,370 mg. sodium sulfate each day. The wastes contained 1,140 mg. per liter C.O.D. after all salts were added, with a 5-day B.O.D. of 460 mg. per liter and 2,210 mg. per liter sulfates.

Acetate

The four acetate units were started at approximately 200 mg. per liter suspended solids and, with the exception of the sulfate unit, were operated over a 34-day period. The sulfate unit was operated for only 16 days because of difficulties. The units were allowed to build up to equilibrium, as measured by a constant mixed liquor suspended solids concentration. This equilibrium required approximately 20 days to be established. The data were then collected over the last 8 days operation and averaged to give the data shown in Table I.

TABLE I.—Oxygen Balances for the Average Daily Feeding of Sodium Acetate

Item	Oxygen (mg.)			
	Aeration	Nitrates	Sulfates	No Oxygen
Oxygen:				
In system	35	45	50	535
Added	1,070	1,070	1,070	1,070
Oxidized	875*	880	720	0
Remaining	230	235	400	1,605
Solids (as oxygen equivalent):				
Sampling	75	50	165	0
Effluent	50	50	55	0
Total	125	100	220	0
Remaining	105	135	180	1,605
Unstabilized:				
Effluent	70	90	100	1,070
In system	35	45	50	535
Total	105	135	150	1,605
Unaccounted		0	30	0

* Calculated.

Aeration

The aeration unit quickly built up the suspended solids concentration to an average of 2,880 mg. per liter during the last 8 days. This solids level was maintained by a balance between acetate fed daily and the solids lost in the effluent and in sampling. Although the effluent C.O.D. was 90 mg. per liter, the 5-day B.O.D. was only 3 mg. per liter. The high C.O.D. to low B.O.D. is typical of well-stabilized effluents containing bacterial slime polysaccharides that are not degraded by bacteria. The acetate activated sludge was a typical, well-stabilized activated sludge. The animal population was entirely rotifers. The presence of the rotifers confirmed the low B.O.D. in the effluent.

Nitrates

The nitrate system had no difficulty in starting. The mixed liquor suspended solids climbed to an average of 1,980 mg. per liter over the last 8 days operation. The effluent B.O.D. of the nitrate unit, like that of the aeration unit, was low compared to the C.O.D. (7 mg. per liter 5-day B.O.D. and 90 mg. per liter C.O.D.). The bacteria had no difficulty in degrading the acetate and reducing the nitrates. Approximately twice as much NO_3–O was supplied to this unit as required in order to determine if the nitrates were completely reduced to nitrogen gas or if all of the nitrates were partially degraded. Nitrate, nitrite, ammonia and dissolved oxygen analyses showed that the required quantity of nitrates broke down to nitrogen gas without any build-up of nitrites, ammonia or dissolved oxygen.

The oxygen balance data indicated that 1,050 mg. NO_3–O were reduced in accordance with the reaction given. Of the 3 atoms of oxygen in the nitrate molecule, 2.5 atoms were available for

oxidizing the organic matter, but the other 0.5 atom was tied up with sodium.

The nitrate sludge was a light tan color, as was the aeration activated sludge. The floc was a normal appearing bacteria floc. The most notable feature of the nitrate floc was the absence of microscopic animals. The lack of dissolved oxygen in the unit prevented the higher animals from growing, but did not prevent good floc formation. The absence of an animal population caused a highly turbid effluent, because the free-swimming bacteria were not being removed.

Sulfates

The sulfate unit did not start with the initial 11-ml. inoculum of mixed liquor. One hundred ml. of raw sewage failed to get the unit started. Even an inoculum of supernatant from an active anaerobic digester failed to start the unit. The unit was finally started by using a very large inoculum of a laboratory activated sludge. The unit was operated 12 days before analyses were made. The average operating data for the sulfate unit (Table I) were taken over the last four days of operation. The mixed liquor suspended solids averaged 11,500 mg. per liter. The unit was quite active in reducing the sulfates, as indicated by the decrease in sulfates, a very distinct hydrogen sulfide odor, and a black metallic sulfide precipitate.

The oxygen balance indicated that the four oxygen atoms in the sulfate were all available for oxidation of the acetate. The two sodium atoms were balanced by the sulfur atom. Actually, the sulfur took up two hydrogen atoms and the two sodium ions were taken up by one oxygen atom. The exact balance of ions depends on pH and the ions themselves, but the net effect is that the equivalent of four atoms of oxygen are available for oxidation.

No Oxygen

In the absence of an oxygen source and with a limited bacteria inoculation, it was not possible to build up a biological sludge which could degrade the acetate. This was expected, as there was not enough time to build up a methane bacteria culture.

Industrial Waste

A complex chemical waste was studied to show that the pattern of oxidation was basic with regard to the ultimate hydrogen acceptor and was not a factor of the organic matter other than its oxidizability. The industrial waste contained 1,470 mg. per liter SO_4–O in addition to 1,140 mg. per liter C.O.D. An additional 1,070 mg. per liter SO_4–O was added to the waste to supply twice the SO_4–O concentration required to oxidize the organic matter. In both the nitrate unit and the aeration unit 2,340 mg. NO_3–O was added to complete the oxygen pattern. The variable nature of the industrial waste made it impossible to make an average balance as in the case of the acetate system. In-

TABLE II.—Oxygen Balances for the 24th Day Feeding of Industrial Waste

Item	Oxygen (mg.)		
	Aeration	Nitrate	Sulfate
Oxygen:			
In system	50	135	85
Added	1,140	1,140	1,140
Oxidized	935*	990	750
Remaining	255	285	475
Solids (as oxygen equivalent):			
Sampling	65	80	70
Effluent	40	40	50
Total	105	120	120
Remaining	150	165	355
Unstabilized:			
Effluent	100	90	200
In System	50	45	100
Total	150	135	300
Unaccounted	—	30	55

* Calculated.

stead, an oxygen balance was made for the 24th day of operation (Table II).

Aeration

The mixed liquor suspended solids on the 24th day were 2,560 mg. per liter. There was no reduction of sulfates and an increase in nitrates due to oxidation of the excess ammonia. The bacteria definitely preferred dissolved oxygen to either form of chemical oxygen. This is not a new observation, but merely confirmation of a well-established field observation.

Nitrates

As expected, the nitrate system grew up readily to 3,300 mg. per liter suspended solids in 34 days. As in the aeration system, the higher energy form of oxygen was used in the stabilization of the organic matter.

Sulfates

In the absence of dissolved oxygen or nitrate oxygen the bacteria had no difficulty in utilizing the sulfates. The sulfate sludge was built up more easily than in the acetate system. Activated sludge from an aeration system fed the industrial waste was used as the seed of sulfate-reducing bacteria. In 24 days the mixed liquor suspended solids rose to 1,830 mg. per liter.

No Oxygen

Because the waste contained sulfates, it was impossible to run an anaerobic, no-oxygen unit.

Discussion

This study has demonstrated the well-known principle of oxidation based on dissolved oxygen as the primary hydrogen acceptor, with nitrates secondary and sulfates tertiary. Although this pattern of oxidation has been considered important, it has never been fully utilized in sanitary engineering.

As has been shown in these studies, it is possible to completely stabilize an organic waste with either nitrates or sulfates as the oxygen source. By applying known principles of biological flocculation (3) it is possible to develop a biological sludge under anaerobic conditions which will flocculate in the same manner as normal activated sludge and will stabilize the organic matter to the same degree as activated sludge. The only difference is that the normal activated sludge effluent would be relatively clear while the effluent from the anaerobic system would be turbid with dispersed bacteria.

It is readily recognized that it would not be economically feasible to treat organic wastes with nitrates, but there are some problems where the use of nitrates as an oxygen source can solve a particular problem. Some chemical process wastes contain considerable nitrates. By the use of the principles of oxidation it would be possible to completely reduce the nitrates in the waste to nitrogen gas. Nitrate-containing wastes are not very common, but they can cause considerable problems if discharged into a watercourse which is eventually used as a source of drinking water.

For the most part, nitrates have been used as a supplemental oxygen source, but the literature on this point is conflicting. Porges *et al.* (4) found that nitrates were not available as an oxygen source in the stabilization of dairy wastes by activated sludge either aerated or unaerated. Other investigators (5)(6)(7) showed that the addition of nitrates to streams prevented anaerobic conditions. Sanborn (8) found that the addition of nitrates to cannery waste lagoons prevented sulfide odor nuisances. Basically, the problem is one of proper microorganisms. In this study, approximately one week was required to build up enough of the proper bacteria to completely stabilize the organic matter added each day. The denitrifying bacteria are actually

quite common in nature and will have little difficulty in establishing themselves in any anaerobic or partially anaerobic system where ample nitrates exist.

Sawyer (9) has studied the problem of denitrification in the secondary settling tank of activated sludge systems. He has shown that the denitrifiers will produce enough gas to cause the activated sludge to rise to the surface of the settling tank and partially be lost in the effluent.

Denitrification will occur only when there is an excess of organic matter to be stabilized, ample nitrates or nitrites, and a deficiency of dissolved oxygen. Kraus (10) made good use of this principle at Peoria, Ill., where he had difficulties with his activated sludge process. By aerating the supernatant from the anaerobic digesters, the excess ammonia was converted to nitrates. Adding the aerated supernatant to the head of the aeration tank, three things were accomplished, as follows:

1. The nitrates supplied nitrogen to a nitrogen deficient combination of sewage and industrial waste.
2. The nitrates supplied oxygen at the head end of the aeration tank when the demand for oxygen exceeded the supply of dissolved oxygen.
3. The digested solids added mass to the activated sludge and increased its settleability.

Although sulfates form an oxygen source, they do not form a desirable oxygen source as far as the sanitary engineer is concerned. The reason for this is simple—sulfate reduction yields hydrogen sulfide. Thus, the sanitary engineer is interested in the principles of oxidation as a means of understanding how to prevent sulfate reduction. Unlike nitrate reduction, which is brought about by several different groups of bacteria, sulfate reduction is the work of only one group, the *Desulfovibrio*. But the *Desulfovibrio* are so common in nature that it makes little difference that there is only one family. The *Desulfovibrio* are strict anaerobes, which grow up only after all the dissolved oxygen and all the nitrates have been removed from the solution. But once the dissolved oxygen and nitrates are removed, the *Desulfovibrio* quickly go to work on the sulfates and the remaining organic matter.

Sulfate reduction is a problem in three areas of sanitary engineering, including sewers, settling or holding basins, and anaerobic digesters.

In sewers, sulfate reduction has long been a headache. The basic problem lies in time of contact between the microorganisms and the organic matter. In the case of sulfate reduction there must be considerable numbers of bacteria at work before hydrogen sulfide is lost from the sewage to the atmosphere. If sewage flows rapidly with normal turbulence, there will be little opportunity for sulfate reduction to occur. The problem begins to exist when grease deposits build up in the sewers. Normally, the common soil bacteria remove all of the dissolved oxygen from sewage and leave the *Desulfovibrio* to metabolize the precipitated organic matter. In this way, large masses of sulfate-reducing bacteria build up in the sewer and create hydrogen sulfide problems.

The best control of the sulfate-reducing bacteria is through proper design of sewer systems to prevent grease deposits. Because this cannot be done in many systems already built, the critical areas in the sewer must be scraped clean of grease deposits at frequent intervals to prevent the build-up of the *Desulfovibrio*. Efforts to control the *Desulfovibrio* by chlorination or toxic compounds have not been economically successful, but have been useful in a few isolated instances.

The control of *Desulfovibrio* by the addition of specialized cultures of bacteria has been proposed (11), but is fundamentally unsound. The special-

ized bacteria do not metabolize the organic matter by any unusual oxidation mechanism and merely reduce the meager oxygen resources more rapidly than normal. This can result in stimulation of the *Desulfovibrio* rather than suppression.

Failure to remove sludge from a settling tank or from a holding basin often leads to a build-up of sulfate-reducing bacteria. Once again the problem is one of excess organic matter with no other source of oxygen except sulfates.

The anaerobic digester is the most common source of sulfate reduction in waste treatment. The lack of sufficient hydrogen acceptor in a digester prevents complete stabilization of the organic matter. The sulfate reducers find the anaerobic digester to their liking and produce as much hydrogen sulfide as they can find sulfates to reduce. The most common source of organic matter for the *Desulfovibrio* is in the grease. It is believed that the variation in grease reduction in similar digesters in different areas can be traced, in part, to the degree of sulfate reduction which takes place.

Control of sulfate reduction can be stated quite simply—supply sufficient dissolved oxygen or nitrates to meet the demand for oxygen. Applying this simple statement of fact is not always an easy or an economic solution to the problem. This is where the engineers' ingenuity is taxed to the fullest.

Basically, bacteria stabilize organic matter only as a means of survival and perpetuation of the species. The bacterial stabilization of organic matter will always proceed along the path that yields the maximum quantity of energy per unit of organic matter metabolized. This means that dissolved oxygen will always be the hydrogen acceptors as long as it is available. Nitrates are quickly used as hydrogen acceptor when the dissolved oxygen is depleted. After the nitrates come sulfates. The oxidation of all organic matter by all bacteria follows the same general metabolic schemes, which greatly simplifies understanding the mechanism of oxidation. It is imperative for the engineer to understand the fundamental mechanism of oxidation, both aerobic and anaerobic, in the design and operation of waste treatment systems.

Conclusions

The conclusions derived from this study are as follows:

1. The oxidation of organic matter in both aerobic and anaerobic systems is by the same basic process.
2. The oxidation of organic matter is basically hydrogen removal and transfer to an appropriate hydrogen acceptor.
3. The transfer of hydrogen to a hydrogen acceptor is an energy phenomenon in which the highest energy yielding reaction is used first.
4. The hydrogen acceptors, in order of descending energy yields, are dissolved oxygen, nitrates, sulfates, oxidized organic matter, and carbon dioxide.
5. Organic wastes can be completely stabilized by anaerobic biological sludges utilizing nitrates or sulfates as their source of oxygen.
6. Incomplete stabilization of organic matter, as experienced in anaerobic digestion, is the result of insufficient hydrogen acceptor.
7. In nitrates, 2.5 atoms of oxygen are available for oxidizing organic matter.
8. In sulfates, 4 atoms of oxygen are available for oxidizing organic matter.

Acknowledgment

This investigation was supported by a research grant from the National Institute of Allergy and Infectious Diseases, National Institutes of Health, U. S. Public Health Service.

References

1. Lamanna, C., and Mallette, M. F., "Basic Bacteriology." Williams and Wilkins Company, Baltimore, Md. (1953).
2. Lange, N. A., "Handbook of Chemistry." 8th Edition, Handbook Publishers Inc., Sandusky, Ohio (1952).
3. McKinney, R. E., "Biological Flocculation." *Biological Treatment of Sewage and Industrial Wastes, Vol. 1, Aerobic Oxidation.* Reinhold Publishing Corp., New York, N. Y. (1956).
4. Porges, N., Pepinsky, J. B., Jasewicz, L., and Hoover, S., "Biochemical Oxidation of Dairy Wastes. III. Failure of Sodium Nitrate as a Source of Oxygen." THIS JOURNAL, **24**, 7, 874 (July, 1952).
5. Fales, A. L., "Treatment of Industrial Wastes from Paper Mills and Tannery on Neponset River." *Ind. Eng. Chem.*, **21**, 216 (1929).
6. Carpenter, W. T., "Sodium Nitrate Used to Control Nuisances." *Water Works and Sewerage*, **79**, 175 (1932).
7. Lawrance, W. A., "The Addition of Sodium Nitrate to the Androscoggin River." THIS JOURNAL, **22**, 6, 820 (June, 1950).
8. Sanborn, N. H., "Nitrate Treatment of Cannery Waste." *The Canner*, **92**, 16, 12 (1941).
9. Sawyer, C. N., and Bradney, L., "Rising of Activated Sludge in Final Settling Tanks." *Sewage Works Jour.*, **17**, 6, 1191 (Nov., 1945).
10. Kraus, L. S., "The Use of Digested Sludge and Digester Overflow to Control Bulking Activated Sludge." *Sewage Works Jour.*, **17**, 6, 1177 (Nov., 1945).
11. Reid, G. W., Imel, C., and Baker, W. W., "Sewer Odors." *Pub. Works*, **87**, 90 (1956).

STATE AID FOR CONSTRUCTION ON SEWAGE TREATMENT PLANTS

Maine

The Maine Legislature (Chapter 388, P.L. 1957) authorized the Maine Water Improvement Commission to pay up to 20 per cent of the total cost, or two-thirds of the total Federal contribution under Public Law 660, 84th Congress, whichever is less, for the construction of sewage and waste treatment plants and interceptor sewers. Payments may be made to a municipal or quasi-municipal pollution abatement construction program which has received Federal approval. $836,000 has been appropriated for the next two years.

Maryland

The Maryland legislature authorized the creation of a state debt of $5,000,000 to supplement grants to municipalities by the Federal Government for the construction of sewage treatment facilities. The total contribution of federal and state monies under the provision of this new law cannot exceed 40 per cent of the total cost.

Vermont

The 1957 General Assembly of Vermont approved an act making available, through a $1,000,000 bond issue, grants to pay 20 per cent of the cost of constructing or improving municipal sewage treatment facilities. The total contribution possible under this law is 50 per cent of the cost of construction—20 per cent state funds and 30 per cent Federal funds.

CONTINUING RESEARCH RELATED TO DETERGENTS IN WATER AND SEWAGE TREATMENT *

By H. V. Moss †

Monsanto Chemical Company, St. Louis, Mo.

Some of the problems associated with synthetic detergents in sewage and water treatment were reviewed in 1956 by Coughlin (1). He reported the initiation of research by the Association of American Soap and Glycerine Producers at four universities, as well as the creation of two sub-committees to study analytical methods for accurate determination of alkylbenzene sulfonate and phosphates present in low concentrations in water and sewage. This progress report is to briefly review the various university research projects, pending completion and ultimate publication of the work.

Biological Degradation of Alkylbenzene Sulfonate

There has been concern over the resistance to biological degradation of synthetic detergents that find their way into conventional sewage treatment plants and more recently Hammerton (2) and Sawyer (3) have reported laboratory investigations on biological degradation of a variety of synthetic detergents, including alkylbenzene sulfonate (henceforth referred to as ABS). House and Fries (4), in tracing the fate of radioactive ABS introduced into a small activated sludge sewage treatment plant, found significant ABS removal by secondary treatment.

Because of the predominance of ABS as the organic active constituent of synthetic detergent formulations and the apparent greater resistance of this compound to bio-degradation, attention has been focused on this product in research investigations sponsored by the Association.

M.I.T. Project

With the evidence that ABS is, after all, not completely resistant to bio-degradation, the Association's research project at the Massachusetts Institute of Technology, under the direction of Professors Rolf Eliassen and Ross E. McKinney, has as its objective the isolation or development of strains of bacteria which could metabolize and thereby degrade ABS, either preferentially or at least concurrently with other organic material in domestic sewage. Thus, by use of such bacteria in normal secondary stages of existing sewage treatment plants, a solution to the problem of portions of ABS passing undestroyed into the sewage effluent would be achieved.

In light of previous experience at M.I.T. in similar areas, accomplishing the objectives of the project looked promising and experimental studies were undertaken using a standard ABS of the polypropylene type supplied by the committee.

At this stage of the investigation it can be said that a variety of identified common soil-born bacteria normally found in activated sludge utilize ABS at a slow rate and that some proportion, yet to be fully defined, of ABS that enters conventional sewage treatment plants can be expected to be altered by bacterial decomposition.

* Presented at 1957 Annual Meeting, Assn. of American Soap and Glycerine Producers; New York, N. Y.; Jan. 25, 1957.

† Vice-Chairman, Technical Advisory Comm., Assn. of American Soap and Glycerine Producers.

Whether larger amounts of entering ABS are partially destroyed to a non-surface active compound is a possibility to be explored.

A significant observation is that ABS present in concentrations normally found in domestic sewage is not toxic to activated sludge bacteria; a question that has been raised from time to time.

Investigation of specialized strains of bacteria capable of completely destroying ABS is continuing.

University of California Project

The University of California project, under the direction of Professors E. S. Crosby and P. H. McGauhey, has as its primary objective the determination of the fate of ABS in the environment and concentrations common to normal sewage treatment. In this work, the operation of a typical commercial sewage treatment plant is simulated and to avoid manipulative difficulties still inherent to colorimetric analysis of ABS in sewage in small concentrations, the use of radioactive ABS combined with extractive procedures is employed to trace ABS through a sewage treating system. By material balances it is intended to show where and in what form the ABS originally entering the sewage plant is discharged.

The type of operation being investigated, which is typical of many activated sludge treatment plants, consists of: (a) primary settling, in which settleable solids are removed and sent to an aerobic digester; (b) secondary treatment with activated sludge where biological degradation takes place; and (c) secondary settling, where activated sludge solids are separated and either returned to the system or discharged to the aerobic digester to maintain a constant solid content in the secondary treatment system.

A great deal of pioneering work has been required in the development of the radioactive, S^{35}-tagged, ABS technique, which is proving to be a useful and powerful tool not heretofore available for carrying out investigations of this type.

Through use of this technique, information is being developed on the influence of operating variables of a conventional sewage plant upon the degree of removal of entering ABS. For example, information is being obtained on the amount of ABS adsorbed by solids settled out at various stages of sewage treatment and the effect of aeration time (possibly related to sludge age) and sludge withdrawal upon removal or biological degradation of the ABS.

It is indicated that the range in ABS concentration which might be expected in sewage produces no important effect on the percentage of ABS removal. Neither, in agreement with indications from the work previously mentioned at M.I.T., is there any apparent effect from such levels of ABS upon the health of the activated sludge solids.

From present indications, it is expected that upon completion of the current project at the University of California a comprehensive picture will be available on how much and to what degree ABS is destroyed in conventional sewage treatment and where the various fragments go. There will also be indications that the degree of ABS removal is dependent upon a number of factors, some of which might be varied in the operation of an existing plant.

From the work on these two projects (M.I.T. and the University of California) there is evidence that if not completely decomposed, a considerable proportion of ABS entering a sewage treatment plant will be degraded biologically so that it no longer will be identified as ABS and presumably will, therefore, no longer be surface active.

Frothing

Background

Of the several questions concerning possible adverse effects of synthetic de-

tergents in the water and sewage area, probably the most emotional has been that directed toward the problem of frothing in sewage treatment plants. Complaints of frothing, with accompanying allegations that synthetic detergents were the cause, go back as far as 1947; these complaints strikingly paralleled the increase in domestic sales of detergents. This has been one problem which readily manifests itself to treatment plant operators and others in the field of sanitary engineering.

It is, therefore, not surprising that frothing in sewage plants has probably caused the greatest outcry against detergents, although it is now generally classed as no more than a nuisance and is being coped with, with increasing success, by such devices at the command of the operator as control of suspended solids, use of surface sprays, and froth-breaking additives.

Frothing has also been the subject of considerable experimental investigation, of which more recent studies are those of Bogan and Sawyer (5) and Munro *et al.* (6), wherein the latter comments that more work should be done on the factors which cause frothing in the absence of any detergent.

University of Wisconsin Project

As a result of this recognized important public relations problem, the research project at the University of Wisconsin, under the direction of Professor G. A. Rohlich, is directed to determining the various causes of frothing in sewage treatment plants and thereby to seek means of eliminating or at least minimizing the froth nuisance.

To date, studies have been confined to causative phases of the question, with little if any time devoted to establishing means of diminishing froth.

The majority of replies to a questionnaire directed to several hundred activated sludge treatment plants in the United States showed that frothing occurred to some degree and indicated that frothing is more prevalent during periods of low flow and weaker sewage. A substantial number of those who replied to the questionnaire cited other factors than detergents as being, in their opinion, responsible for frothing in their plants. The large majority of those reporting frothing expressed the belief that frothing has no effect on plant efficiency.

In a field survey of several activated sludge plants it was also observed that frothing was more prevalent during periods of low flow, although frequently ABS content was lower at those times than during high flow. In addition, there was an indication that at a relatively constant level of ABS there was considerable variation in the degree of frothing, with one sample showing none at all. One interesting observation is the fact that at one plant, which has parallel aeration tanks receiving exactly the same sewage, frothing at times occurred in one but not in the other aeration tank. Among other factors investigated, it is indicated from this survey that increase in organic nitrogen content contributes to frothing tendencies.

Laboratory investigations still in progress, to determine the effect of basic sewage components on frothing, point to the fact that proteins and protein degradation products may play an important part in accentuating or stabilizing froth. This is in agreement with the previously mentioned observation relating to organic nitrogen content.

It is anticipated on completion of these investigations that whereas ABS will certainly not be eliminated as a factor in the froth picture, it will by no means be found responsible for all the ills put at its doorstep. It will not be surprising to conclude, as a result of this work, that frothing in sewage plants would not cease if by some means the American public were made willing to completely forego the use of synthetic detergents.

The original objective of establishing

the various factors that affect frothing and seeking means of controlling it is still before the researchers.

Effect of Phosphates on Water Treatment

It is known that modern synthetic detergents contain, as relatively major constituents, inorganic condensed phosphate salts in the form of alkali tripoly and pyrophosphate. These salts possess unique properties that enhance functional performance of detergent formulations.

Problems

It has been suspected that condensed phosphates emanating from domestic waste-wash waters could ultimately find their way through surface streams into water treatment plants, and because of the inherent peptizing and dispersing properties of the condensed phosphates, interfere with normal coagulation and sedimentation operations practiced in conventional water purification.

Among investigations in this area are those of Lea *et al.* (7), Smith *et al.* (8), and Howells and Sawyer (9). Lea *et al.* found it possible to remove most of the soluble phosphate from sewage plant effluent by the use of common coagulants and investigated mechanisms involved in the removal of phosphate from solution. Smith and coworkers found in laboratory experiments that "complex" phosphates in low concentrations interfere with alum coagulation, but that this interference can be overcome by increased alum dosage. Howells and Sawyer found sodium tripolyphosphate and tetrasodium pyrophosphate, when present in concentrations of 2 to 10 p.p.m. in freshly prepared solutions of a natural water (presumed by this author to be relatively free of hardness), to interfere with alum coagulation, which interference could be overcome by heavier alum dosage.

Except for the work by Lea *et al.*, who employed sewage effluents with naturally contained phosphates, it should be observed that the other investigators cited conducted experiments wherein the condensed phosphates were added as such.

It is known that all inorganic condensed phosphates are subject to hydrolytic degradation to simple orthophosphates, which do not possess to the same degree the properties afforded by the parent compounds, and that the rate of degradation is affected by several environmental factors (10). Furthermore, Karl-Kroupa *et al.* (11) reported the accelerating effect of various common living organisms upon degradation of tripolyphosphate.

It is therefore possible that complex phosphates in synthetic formulated detergents are appreciably altered in their circuitous and varied exposure from their use in the home to the raw supply of a water treatment plant.

University of Illinois Project

Accordingly, the research project sponsored by the Association at the University of Illinois has the following major objectives:

1. To establish the levels and kinds of phosphates normally present in typical surface waters that are known to receive sewage plant effluents and that serve as raw water supplies for water treatment plants.
2. To determine whether complex phosphates persist as such in their passage through sewage treatment plants, surface streams, and ultimately to water treatment plants, or are decomposed to simple relatively inactive orthophosphates.
3. If complex phosphates do persist and are found to be present in raw water supplies, to determine what effect polyphosphates have on water purification operations when present in concentrations normally found in surface waters.

From a survey still under way of streams in Illinois that are known to

receive sewage effluents upstream from the sampling points, it is already indicated that the concentration of condensed phosphate present in surface waters, when determined by the analytical method under investigation by the Phosphate Sub-Committee of the Association (whose activities are reported later), average significantly under 0.5 p.p.m. and that rarely does condensed phosphate concentration exceed 1.0 p.p.m.

Interesting is the indication that phosphates present in sewage effluents already consist largely of orthophosphate.

Not surprisingly, it also begins to be apparent that phosphates in surface waters originate in a large measure from other sources than sewage effluent, among which a significant proportion appears to come from land drainage.

In laboratory investigations at the University of Illinois on the stability of complex phosphates in natural waters, degradation of the phosphates has been demonstrated. This supports the hypothesis that condensed phosphates do not persist interminably in natural waters.

Despite present indications of innocuous concentrations of complex phosphates in raw waters, investigations are under way to determine in a pilot plant the effects of polyphosphates in normal and maximum concentrations encountered in raw water supplies upon flocculation and sedimentation processes employed in water purification.

Analytical Methods

Accurate and relatively simple methods for analysis of ABS and phosphates in low concentrations in surface waters and sewage are essential tools in furthering investigations of the types described, in addition to providing other investigators in these areas with better yardsticks to use in their work.

Coughlin (1) told of the existence of two committees engaged in developing analytical methods; one for ABS and one for phosphates.

ABS

The Sub-Committee for Analysis of ABS has developed a method whose details have been published (12). This method is admittedly complicated, requires specialized equipment, and therefore is not suitable for routine work. The committee recognizes this and is endeavoring to develop a much simpler but still accurate procedure.

Associated with and sparked by the work of the ABS Analytical Committee, Fairing and Short (13) have developed an alternative method that has been demonstrated to be applicable to analysis of sewage as well as water. Although somewhat simpler than the previously mentioned procedure, it can hardly be said that this alternative method is truly simple. Search for a method at least as easy as the currently employed methylene-blue test or the more recent methyl-green method of Moore and Kolbeson (14), which are subject to interference caused by other impurities in natural waters and sewage, is still sorely needed.

Phosphates

In the realm of analytical methods for phosphates, the Phosphate Technical Advisory Sub-Committee, originally formed in 1955 to cope with all public problems purported to be associated with inorganic polyphosphates in formulated detergents, undertook as its first assignment the development of test methods for detecting minute amounts and varieties of phosphates in surface waters and sewage.

At this point, a practical method capable of detecting and differentiating between simple and condensed phosphates at fractional parts per million in distilled water has been proved out and employed with a fair measure of accuracy on surface waters and sewage

effluents. Additional refinements or modifications are now being worked on to improve accuracy of the method when applied to surface waters and sewage. It is expected that this group will devise a simple workable procedure.

Aside from comprehensive surveys being made in the project at the University of Illinois on the levels of phosphate presently existing in surface waters, an interesting set of data developed through collaborative analyses by members of the Phosphate Group shows, in samples of widely distributed normal surface waters, total phosphate concentrations ranging from 0.02 to 0.66 p.p.m., with apparent condensed phosphate ranging from 0.00 to 0.49 p.p.m. Among the samples taken was one from the primary effluent of the Chicago sewage plant, which was found to contain 12.1 p.p.m. total phosphate, of which 10 p.p.m. was present as fully degraded orthophosphate.

In the work of the Phosphate Group to date, no effort has been made to differentiate between different forms of polyphosphate that may exist in surface waters. Indeed, because of low levels that appear to be present, it may not be necessary to do so; but should the need arise, it is felt that the paper chromatographic method by Karl-Kroupa (15) for differential analysis of phosphate mixtures can be adapted.

Summary

It appears from the current investigations that alkylbenzene sulfonate in concentrations now present in sewage does not affect bacterial life or otherwise significantly affect efficiency of operation of a sewage treatment plant. The problem in this area resolves itself primarily to one of frothing, and methods are being developed to cope with it.

It is nonetheless apparent that ABS in raw sewage is not completely eliminated by existing conventional sewage treatment and some proportion leaves the plant in its original or partially degraded form through the effluent. There are indications that by control of operations in a sewage treatment plant greater removal of ABS can be achieved in the course of sewage treatment.

At this stage, there is little promise that specialized strains of bacteria capable of completely degrading ABS can be made to subsist in sufficient concentrations in a sewage plant to be effective.

In relation to phosphates, on which attention has been focused as to their possible interference in water treatment operations, accumulating evidence points to the fact that the possible offenders (polyphosphates) do not find their way into raw waters in sufficient concentrations to pose a real problem.

It is thus apparent that questions associated primarily with ABS have not yet been adequately answered, neither was it expected that in 18 months of research would a solution to such a complex problem, fraught with so many variables, be in hand at this time.

With this realization, the Association's Research Committee has concluded that, in the interest of the public and the industry, research investigations under sponsorship of the Association be continued.

References

1. Coughlin, F. J., "Detergent Research Related to Water and Sewage Treatment." *Soap and Chem. Spec.*, **32**, 51–53, 67–69, 71 (1956).
2. Hammerton, C., "Observations on the Decay of Synthetic Anionic Detergents in Natural Waters." *Jour. Appl. Chem.*, **5**, 517 (1955).
3. Sawyer, C. N., "Biochemical Behavior of Synthetic Detergents." *Ind. and Eng. Chem.*, **48**, 235 (1956).
4. House, R., and Fries, B. A., "Radioactive ABS in Activated Sludge Sewage Treatment." THIS JOURNAL, **28**, 4, 492 (Apr., 1956).
5. Bogan, R. H., and Sawyer, C. N., "Biochemical Degradation and Froth For-

mation. III. Relationships Between Biological Degradation and Froth Persistence." THIS JOURNAL, **28**, 5, 637 (May, 1956).

6. Munro, L. A., Yatabe, J., and Abrams, W. J., "Pilot-Plant Studies of Frothing in Sewage Treatment Plants." THIS JOURNAL, **28**, 12, 1232 (Dec., 1956).
7. Lea, W. L., Rohlich, G. A., and Katz, W. J., "Removal of Phosphates from Treated Sewage." THIS JOURNAL, **26**, 3, 261 (Mar., 1954).
8. Smith, R. S., Cohen, J. M., and Walton, G., "Effects of Synthetic Detergents on Water Coagulation." *Jour., Amer. Water Wks. Assn.*, **48**, 1, 55 (1956).
9. Howells, D. H., and Sawyer, C. N., "Effect of Synthetic Detergents on Chemical Coagulation of Water." *Water and Sew. Works*, **103**, 71 (1956).
10. Van Wazer, J. R., Griffith, E. J., and McCullough, J. F., "Structure and Properties of the Condensed Phosphates. VII. Hydrolytic Degradation of Pyro and Tripolyphosphate." *Jour. Amer. Chem. Soc.*, **77**, 287 (1955).
11. Karl-Kroupa, E., Callis, C. F., and Seifert, E., "Study of Factors Affecting Stability of Condensed Phosphates in Very Dilute Solutions." *Ind. and Eng. Chem.*, **49** (1957).
12. Sallee, E. M., Fairing, J. D., Hess, R. W., House, R., and Maxwell, P. M., "Determination of Trace Amounts of Alkylbenzene Sulfonate in Water." *Anal. Chem.*, **28**, 1822 (1956).
13. Fairing, J. D., and Short, K. F., "Spectrophotometric Determination of Alkylbenzene Sulfonate Detergents in Surface Water and Sewage." *Anal. Chem.*, **28**, 1827 (1956).
14. Moore, W. A., and Kolbeson, R. A., "Determination of Anionic Detergents in Surface Waters and Sewage with Methyl Green." *Anal. Chem.*, **28**, 161 (1956).
15. Karl-Kroupa, E., "Use of Paper Chromatography for Differential Analysis of Phosphate Mixtures." *Anal. Chem.*, **28**, 1091 (1956).

LAW AND CONTEMPORARY PROBLEMS

Water pollution administrative personnel and others interested in water pollution and water resources will be interested in the Spring 1957 and Summer 1957 issues of *Law and Contemporary Problems*, published by the Duke University School of Law. These issues present symposiums on river basin development and water resources management.

Topics of the river basin development symposium are: perspective, engineering aspects, economic dynamics, social consequences, evaluation, politics, basic water rights doctrines and implications, and model state water code for river basin development. The water resources management symposium features: Federalism and water resources management, TVA, Muskingum (Ohio) Watershed Conservancy District, small watershed program, role of private enterprise, national water resources administration, and national water resources policy.

Single copies of each symposium are available at $2.00 each postpaid. Information may be obtained from *Law and Contemporary Problems*, Duke University School of Law, Durham, N. C.

SETTLING AND COMPACTION CHARACTERISTICS OF BIOLOGICAL SLUDGES

I. GENERAL CONSIDERATIONS *

By W. Wesley Eckenfelder, Jr., and Norman Melbinger

Respectively, Associate Professor of Civil Engineering and Student, Manhattan College, New York, N. Y.

The performance of secondary sedimentation units in biological processes is related to both the physical and chemical nature of the sludge and to the hydraulic characteristics of the sedimentation basin. Sludge characteristics have been studied by Rudolfs and Lacy (1) and Heukelekian and Weisberg (2). Factors affecting hydraulic design have been discussed by Anderson (3) and Sawyer (4). Theoretical discussions of flocculent sludge settling have been given by Brown and Associates (5), Coulson and Richardson (6) and Fitch (7).

This paper describes laboratory procedures which may be employed to characterize the settling and compression of activated sludge. Considerable work remains to be done to develop scale-up factors between laboratory and prototype sedimentation.

Activated sludge is a flocculent sludge composed of a miscellaneous collection of microorganisms, amorphous matter, and inorganic solids. The settleability of an activated sludge is characterized by the sludge volume index (SVI) which is defined as the volume of sludge settled in a specified time interval, divided by the sludge concentration, and has the units milliliters per gram. The sludge index is also used as a criterion of plant performance. In general a Mohlman Sludge Index (SVI) of 40 denotes good sludge, whereas an SVI of 200 indicates a poor or bulky sludge. The SVI will generally vary with the mixed liquor suspended solids content for the same sludge. Low index sludge may contain as much as 98 per cent water in the sludge particles with a density of 1.005 (8). The settling properties of a sludge will be greatly influenced by changes in physical and chemical characteristics of the process which in turn alter the biological reaction of the sludge. This is best illustrated by the transition of a low index sludge to a bulking (high index) sludge in the activated sludge process.

Hindered Settling and Compression

In the settling of activated sludge the floc adheres together and the mass of particles settle as a blanket producing a distinct interface between the floc and the supernatant. The settling process occurs as shown in Figure 1 and may be distinguished by three zones.

During the initial settling period (A) the sludge floc settles at a uniform velocity under existing conditions of hindered settling. The magnitude of this velocity is a function of the initial solids concentration. The concentration of solids in the hindered settling zone will remain constant until the interface A approaches interface B. The free settling zone will not exist beyond a critical solids concentration.

As the layer of settled sludge solids increases the settling floc begins to press on layers below and a transition zone B occurs. Through the transition

* Presented at the 1957 Spring Meeting, New York Sewage and Industrial Wastes Assn.; Lake Placid, N. Y.; June 17–18, 1957.

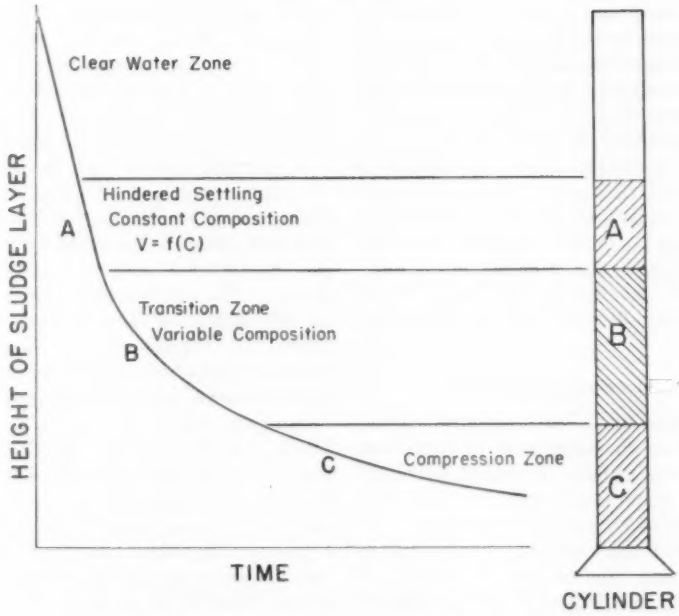


FIGURE 1.—Schematic representation of settling zones.

zone the settling velocity will decrease due to the increasing density and viscosity of the suspension surrounding the particles.

A compression zone C occurs when the floc concentration becomes so great as to be mechanically supported by the layers of floc below. The solids concentration in the compression zone will be related to the depth of sludge and the detention of the solids in this zone. Cummings *et al.* (9) showed that for a given detention period a shallow compression zone depth will yield a higher underflow concentration than a deep depth. As the depth of the sludge blanket is increased the sludge detention in the compression zone must also be increased for a specified underflow concentration.

A clarifier employed in biological treatment processes serves the dual functions of clarifying the liquid overflow and thickening the sludge underflow. The clarification capacity of the unit is related to the settling velocity of the sludge in which the velocity of the sludge interface must be greater than the vertical rise velocity of the liquid at any level. This settling rate may be approximated by the change in interface level with time in batch sedimentation tests. The thickening capacity is related to the depth of sludge in the basin and the time the sludge is

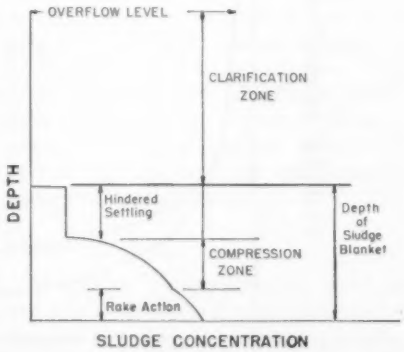


FIGURE 2.—Sedimentation in a secondary settling tank.

in the compression zone. Thickening is enhanced by the hydraulic movement of the sludge blanket and the action of the rakes which break up stratification of the settled sludge. This mechanism is schematically shown in Figure 2. In clarifier operation where the sludge is introduced through a feed well there may be substantially no hindered settling zone. If the clarifier becomes overloaded, a zone of constant composition will develop in the basin which will eventually rise and overflow the basin.

Laboratory Procedure

In order to develop design criteria, the settling characteristics of flocculent sludges are usually evaluated by batch settling tests conducted in graduated cylinders at constant temperature.

As the sludge settles an interface is formed and the change in height of this interface is observed with respect to time. For most sludges, readings at short time intervals are required up to the transition zone. The subsequent compression curve should be developed over an interval of 1 to 2 hr. The initial solids concentration should be recorded. It is usually desirable to check the solids remaining in suspension above the sludge-liquid interface since these will be indicative of possible carryover in the clarified effluent.

A stirring device may be employed to simulate the rake action in clarifiers. This mechanism influences the transition and compression zones by preventing the natural arching action of the sludge. The result of the stirrer action on the height of the sludge layer is shown in Figure 3. In laboratory studies conducted at Manhattan College on several activated sludges, a concentration range of 1,000 to 6,000 p.p.m. was obtained by dilution of returned sludge with effluent. From each dilution 2 l. samples were obtained; one-half of each sample was placed in a quiescent cylinder and the other half was subjected to gentle mixing. The mixer revolved at a speed of 4 r.p.h. In order to cover all operating conditions, settling data should be obtained for the anticipated range of initial solids concentration.

From a plot of the sludge interface

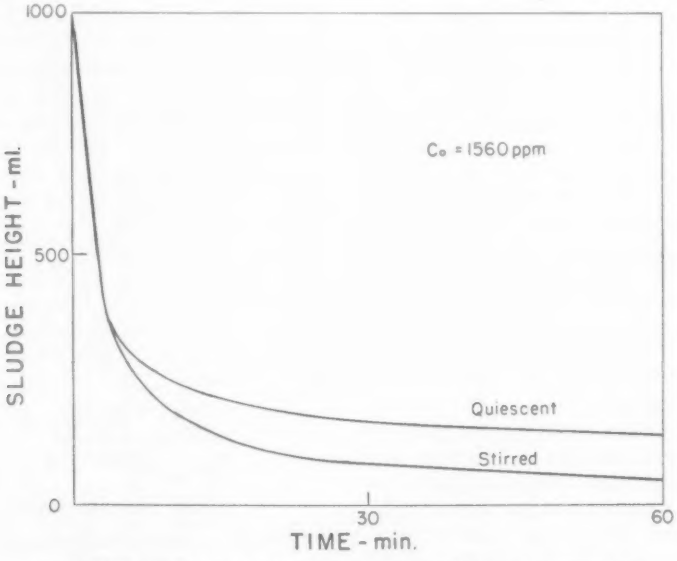


FIGURE 3.—Effect of mixing on sludge settling and compaction.

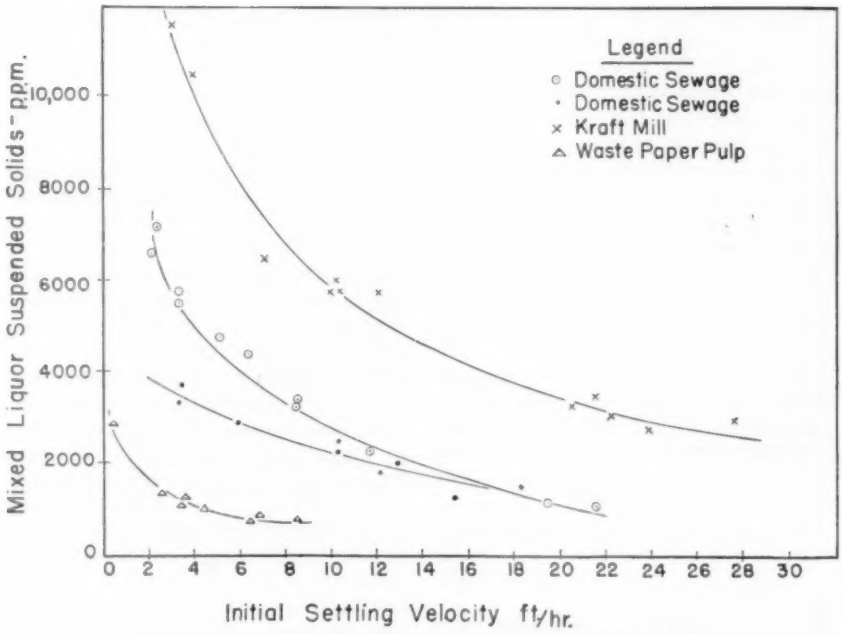


FIGURE 4.—Hindered settling velocity of activated sludge.

level and time, the process design criteria may be developed.

Discussion

Hindered Settling Zone

Zone or hindered settling is represented as the constant rate settling of the sludge-liquid interface which initially occurs in a batch sedimentation test. This settling rate is a function of the initial solids concentration and the flocculation characteristics of the suspension. As the initial concentration is increased the settling velocity of the sludge mass is decreased. The velocity-concentration curve for any sludge will depend on the physical and chemical properties of the sludge and on its flocculating characteristics. A particular sludge may alter its settling properties depending on the biological characteristics of the system (*i.e.* B.O.D. loading, D.O. levels, etc.). The hindered settling curves relating settling velocity and concentration for several domestic and industrial activated sludges is shown in Figure 4. From Figure 4, the hindered settling velocity of domestic sewage activated sludge (sludge index of 100) over a range of mixed liquor suspended solids of 1,000 to 4,000 p.p.m. is 6 to 20 ft. per hour. Activated sludge from Kraft mill oxidation and paper repulping waste oxidation showed a settling velocity range of 10 to 26 ft. per hour over a concentration range of 3,000 to 6,000 p.p.m. and 1 to 8 ft. per hour over a concentration range of 1,000 to 2,000 p.p.m. Camp (8) has reported a range of hindered settling velocity of 16.6 to 32.0 ft. per hour for domestic sewage activated sludge.

Transition Zone

When the sludge interface level in the hindered settling zone approaches the level of sludge in the compression zone a transition zone occurs. The transition zone is characterized by a

critical concentration at which point compression of the settling sludge mass commences. The critical concentration has been found to vary widely with different sludges and to vary with initial solids concentration in most cases. The critical concentration can be estimated from a batch settling test by projecting tangents from the hindered settling zone and the compression zone and bisecting the angle produced by the two tangents. The point at which the bisected angle cuts the settling curve is the approximate compression point. The critical concentration at the sludge interface at the compression point is computed from the relation by Talmadge and Fitch (10):

$$C_o H_o = C_2 H_1$$

Where C_o is the initial concentration of suspended solids in parts per million, H_o is the height of the test cylinder, cm., C_2 is the suspended solids concentration at the interface, and H_1 is the height the sludge would occupy if the entire sludge mass had the same concentration as the interface at the compression point. The term H_1 is obtained by projecting a tangent at the compression point to the sludge height axis. Data for several activated sludges are plotted in Figure 5. The interfacial concentration at the compression point for domestic sewage was found to vary with initial solids concentration and showed a range of 4,000 to 8,000 p.p.m. over an initial solids concentration range of 1,000 to 4,000

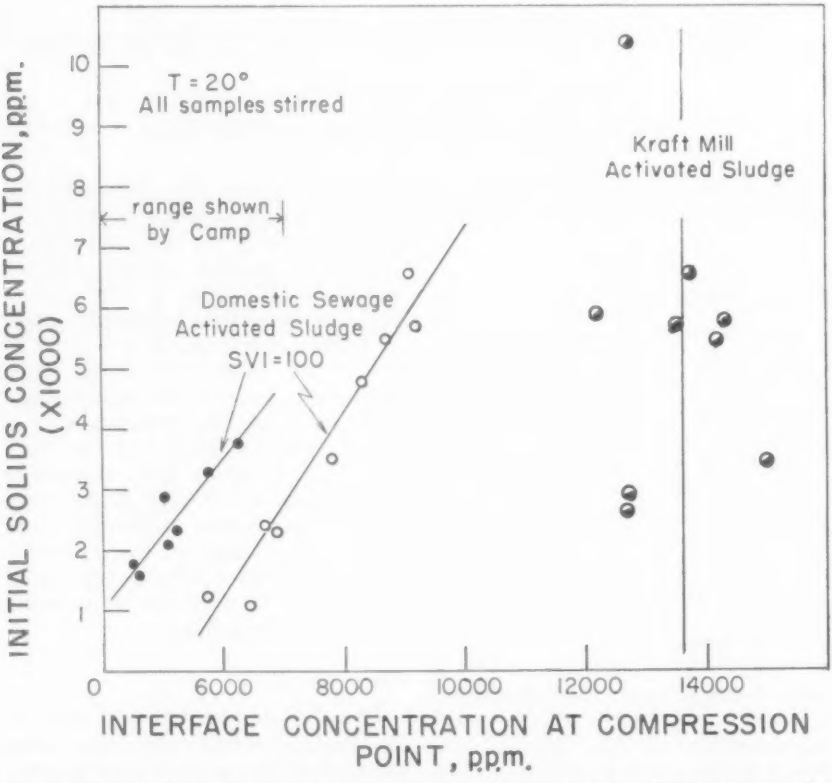


FIGURE 5.—Relation between initial solids concentration and interfacial concentration at the compression point.

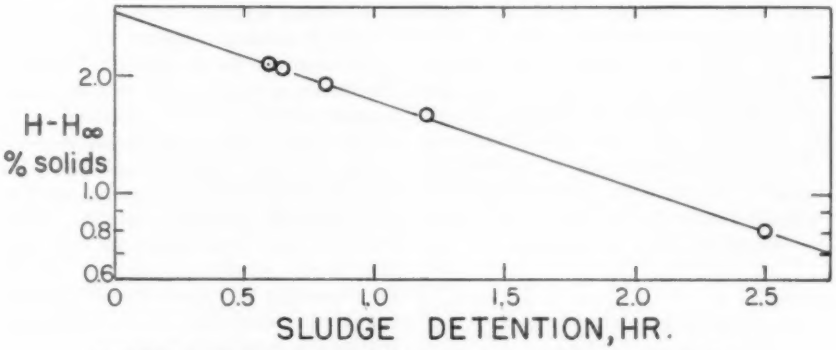


FIGURE 6.—Rate of compaction of domestic sewage activated sludge.

p.p.m. (normal sewage treatment plant operating range). These data are in substantial agreement with results reported by Camp (8). Data from activated sludge from Kraft mill oxidation showed the compression point to be independent of initial solids concentration. The compression points from the non-stirred samples were slightly lower than those for the stirred samples.

Compression Zone

During sludge compression, water is squeezed from the compacting sludge mass. The rate of compaction is low because the displaced fluid has to flow through the small void space within the sludge mass, and it progressively decreases with time as the resistance to liquid flow increases. A relationship has been developed to approximate the rate of sludge thickening with time (6).

$$\frac{dH}{dt} = K(H - H_{oo}) \quad \ldots\ldots (1)$$

Eq. 1 may be integrated

$$2.3 \log. \frac{(H_o - H_{oo})}{(H - H_{oo})} = K(t - t_o) \quad \ldots (2)$$

In Eq. 2, H_o is the height of the sludge layer at the compression point and H_{oo} is the height the sludge will occupy after compression is complete. For most cases H_{oo} must be determined experimentally from a plot of log. $H - H_{oo}$ versus time. Data tabulated by Anderson (3) has been replotted in this form (Figure 6).

Clarifier Design

The size of secondary clarifiers in bio-oxidation systems is related to three design factors:

1. The area required for clarification over the operating mixed liquor suspended solids range. This in turn is related to the allowable overflow rate in order that the vertical liquid rise rate at any level is less than the solids subsidence rate at that level.
2. The area and volume requirements to produce by thickening an underflow of a desired concentration.
3. The permissible retention of the settled sludge in the basin as dictated by its biological properties.

In any given case the tank area and volume will be controlled by one of these three factors.

The overflow rate required for clarification is computed from the free-settling velocity of the sludge. As has been previously discussed, the rate of sludge subsidence must be greater than the rate of liquid rise. This rate is computed using only the overflow from the basin. The overflow rate may be approximated over a wide concentra-

tion range (usually 1,000 to 5,000 p.p.m.) using laboratory data.

The area requirements for sludge thickening may be computed by the methods developed by Talmadge and Fitch (10) and Coe and Clevenger (11). Considering the concentration range over which the basin will function the required unit area (U.A.) may be computed from the relation:

$$\text{U.A.} = \frac{\left(\frac{1}{C_2} - \frac{1}{C_u}\right)}{V_2} \quad \ldots\ldots (3)$$

In Eq. 3 the units of C_2 and C_u are pounds per cubic foot and the unit of V_2 (settling velocity) is feet per day. Thus, U.A. is in square feet per pound of solids per day.

For each settling curve a plot of interfacial settling velocity versus concentration can be developed. Figure 7 illustrates a typical plot of a domestic sewage activated sludge settling curve (SVI = 90). An area should be computed for the desired underflow for various concentrations over the settling curve and the maximum selected as the critical area. This maximum will usually occur at the compression point. By repeating this procedure for a wide range of mixed liquor solids concentrations a maximum area for design can be selected.

The method of Talmadge and Fitch (10) involves a settling test in which the sludge height at various times is plotted against the time to attain that

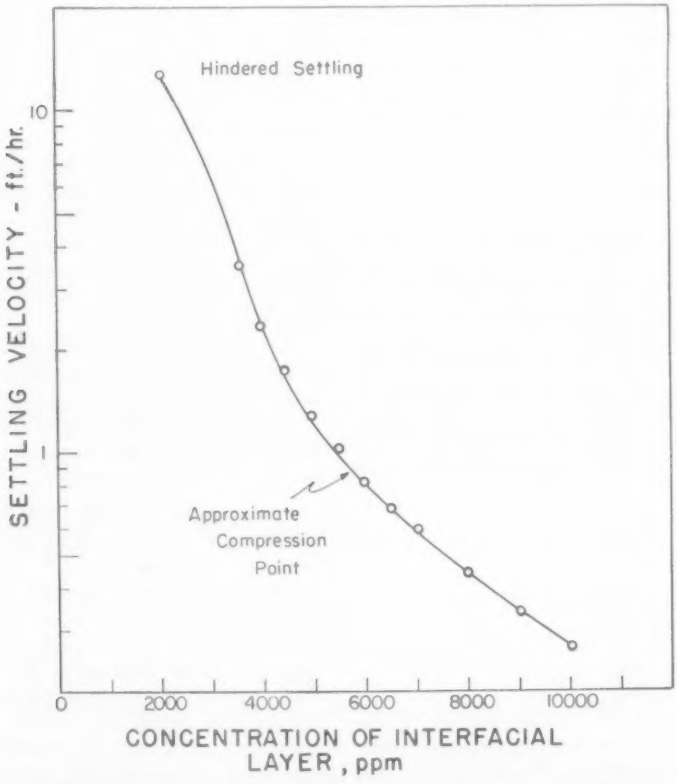


FIGURE 7.—Relation between settling velocity and concentration.

TABLE I.—Conventional Activated Sludge Operation Secondary Sedimentation

Plant	Year	Flow (m.g.d.)	Returned Sludge (%)	Susp. Solids, Returned (p.p.m.)	Susp. Solids, Aeration (p.p.m.)	SVI	Detention (hr.)	Overflow Rate (g.p.d./sq. ft.)	Unit Area (sq. ft./lb./day)
Gary, Ind.	1947	19.9	40.4	3,918	1,807	91	3.1	701	0.066
	1952	24.1	35.7	7,363	1,995	112	2.6	836	0.053
Baltimore, Md.	1940–41	14.4	26.0	—	2,210	113	3.2	580	0.074
	1942–43	12.2	24.1	—	1,706	258	3.8	490	0.115
	1945–47	12.6	21.1	—	927	327	3.8	510	0.208
Greece, N. Y.	1953	1.1	29.8	9,790	744	72	2.2	440	0.280
Indianapolis, Ind.	1952	16.6	29.0	9,200	2,500	86	2.9	719	0.052
Los Angeles, Calif.	1951–52	21.9	—	2,106	215	—	1.95	1,400	0.360
Chicago, Ill.	1945	—	—	15,600	3,290	52	—	860	0.033

height. A tangent is drawn to the point of compression. The intersection of this tangent with the line representing the desired underflow concentration, C_u, determines the time, t_u. This is the time required to attain the desired underflow concentration. A wide range of initial solids should be evaluated and the maximum area in the expected operating range selected.

The required area may be computed from the relationship:

$$\text{U.A.} = 1.1 \times 10^{-5} \frac{t_u R}{C_o} \quad \ldots\ldots (4)$$

The unit of C_o is grams per liter. R is the milliliter per foot in the settling cylinder.

The unit area may be converted to overflow rate on a mixed liquor basis as follows:

$$\text{O.R.} = \frac{120}{(\text{U.A.})(C_o)} \quad \ldots\ldots (5)$$

Overflow rate on a flow-through basis is obtained by multiplying Eq. 5 by the ratio

$$\frac{C_u - C_o}{C_u}$$

When considering biological sludges the underflow concentration which can be developed by compression may be limited. The sludge in a clarifier will consume the available oxygen and progress into an anaerobic state. In sludge with a high rate of activity, this may result in gasification and floating of the sludge to the surface of the unit. As a result, the allowable detention time of the sludge in the clarifier will be very short. For example a sludge from a pharmaceutical waste oxidation (B.O.D. = 5,000 p.p.m.) gasified and floated to the surface after 15 to 30 min. of sedimentation with an aeration period of 16 hr. However, it did not float or gasify after a 24-hr. sedimentation period, when the aeration period was extended to 44 hr. Sawyer and Bradney (12) have shown that sludge flotation due to denitrification can occur through prolonged detention in final clarifiers. Deterioration of the sludge for subsequent aerobic treatment must also be avoided.

It is desirable to conduct a series of tests relating the retention period of the sludge in the clarifier to its clarification and oxidation rate in subsequent aeration with waste. A limiting retention period of the sludge in the clarifier will be established which will in turn produce a limiting underflow concentration. This limiting underflow concentration has been found to vary from 0.5 per cent for a highly active sludge from a cannery waste oxidation to 3.0 per cent for pulp and paper waste oxidation.

Heukelekian and Weisberg (2) showed a general relationship between the SVI and the bound water content of the sludge. A low SVI showed a

bound water content of about 100 per cent, whereas a high SVI showed a bound water content of 380 per cent. Prolonged aeration reduced the bound water content and the SVI. A method employing redox potential has been developed by Nussberger (13) to determine the retention period of activated sludge in final clarifiers.

Table I gives secondary clarifier performance data for several domestic sewage activated sludge plants. For low index sludges a unit area of 0.05 sq. ft. per pound per day appears common while for bulky sludges a higher unit area is required.

Hydraulic Considerations

Density currents are induced in final settling tanks due to the fact that the specific gravity of the sludge mixture is greater than the clarified water in the tank. The activated sludge on entering a settling tank falls almost vertically and then flows along the bottom of the tank toward the outlet end or wall. Currents near the bottom of the tank will establish secondary currents in the water layers above them in a reverse direction. This phenomenon will lead to a carryover of sludge in the peripheral weirs from up-welling currents unless adequate design is considered. Such considerations include increased weir length to decrease lineal overflow rate, in-board weirs, and inlet device design.

Conclusions

The sludge index has severe limitations as a criterion for final settling tank design and operation over a wide range of operating conditions. Laboratory methods previously developed for industrial application have been applied to several domestic and industrial activated sludges. It is hoped that these methods will be compared to prototype operation so that parameters can be developed for the design of final settling tanks in the activated sludge process.

References

1. Rudolfs, W., and Lacy, J., "Settling and Compaction of Activated Sludge." *Sewage Works Jour.*, **6**, 4, 647 (Nov., 1934).
2. Heukelekian, H., and Weisburg, E., "Bound Water and Activated Sludge Bulking." THIS JOURNAL, **28**, 4, 558 (Apr., 1956).
3. Anderson, N. E., "Design of Final Settling Tanks for Activated Sludge." *Sewage Works Jour.*, **17**, 1, 50 (Jan., 1945).
4. Sawyer, C. N., "Final Clarifiers and Clarifier Mechanisms." *Biological Treatment of Sewage and Industrial Wastes.* Vol. 1, *Aerobic Oxidation.* Reinhold Pub. Corp., New York, N. Y. (1956).
5. Brown & Associates, "Unit Operations." John Wiley and Sons, New York, N. Y. (1950).
6. Coulson, J. M., and Richardson, J. F., *Chemical Engineering*, p. 510, McGraw-Hill Book Co., New York, N. Y. (1955).
7. Fitch, E. B., "Sedimentation Process Fundamentals." Paper presented at Second Waste Treatment Conf., Manhattan College, N. Y. (1957).
8. Camp, T. R., "Sedimentation and the Design of Settling Tanks." *Proc. Amer. Soc. Civil Engrs.*, **11**, 895 (1946).
9. Cummings, E. W., Priess, C. E., and DeBord, C., "Continuous Settling and Thickening." *Ind. Eng. Chem.*, **46**, 8, 1164 (1954).
10. Talmadge, W. P., and Fitch, E. B., "Determining Thickener Unit Areas." *Ind. Eng. Chem.*, **47**, 38 (1955).
11. Coe, H. S., and Clevenger, G. H., *Trans. Amer. Inst. Mining Engrs.*, **55**, 356 (1916).
12. Sawyer, C. N., and Bradney, L., *Sewage Works Jour.*, **17**, 6, 1191 (Nov., 1945).
13. Nussberger, F. E., "Application of ORP to the Control of Sewage Treatment Processes." THIS JOURNAL, **25**, 9, 1003 (Sept., 1953).

THE SIGNIFICANCE OF DETENTION IN SEDIMENTATION

By E. B. Fitch

Director of the Westport Laboratories, Dorr-Oliver Inc., Westport, Conn.

It has been asserted repeatedly in the literature that the removal of suspended matter in a sedimentation basin theoretically is governed by overflow rate and not at all by detention time. This idea has not been accepted, however, by all sanitary engineers, and considerable evidence has appeared to indicate that the principle is not universally valid. Therefore, the published theory was criti ally analyzed to determine under what conditions it was necessarily valid, and whether or not these conditions were met in all types of suspensions.

Suspended solids entering a sedimentation basin may be divided into two classes as follows:

Class I—Particles or floccules which maintain their individuality throughout the settling period, hence settle essentially at a constant rate with respect to the suspending fluid.

Class II—Particles or floccules which continue to coagulate or flocculate during the settling process, with consequent changes in settling rate.

An example of Class I solids would be silt; an example of Class II solids, some of the fine organic matter present in raw sewage.

In 1904 Hazen (1) deduced from the known settling behavior of Class I particles that their removal in a settling basin should be a function of overflow rate and not of detention time *per se*. On the basis of postulates as to the mechanism of floeculation, Camp (2)(3) later deduced that essentially the same should be true for particles of the second class also. Several writers, deriving their basic concepts from Camp and taking for granted the validity of his postulates, have urged that all sedimentation basins should be designed primarily on the basis of overflow rate. The continuing use of detention as a design criterion has been deplored.

The theoretical treatment of Camp makes two general assertions concerning the sedimentation behavior in both classes of suspensions:

Assertion I—"The removal of suspended matter in a sedimentation basin is unaffected by the depth of the tank except through the influence of turbulence and bottom scour." In context, this is equivalent to asserting that removal is governed by overflow rate and not by detention *per se*.

Assertion II—Short-circuiting (including density-current short-circuiting) decreases removals.

It appears that these assertions, considered as a pair, are not generally valid. First, it has been shown in an earlier paper (4) that for Class I particles, whereas removal is indeed governed by overflow rate it is not at all affected by density-current short-circuiting. Second, Eliassen (5) has demonstrated that the two assertions are incompatible, and cannot both be generally valid for any sort of suspension.

For the sake of demonstration, suggests Eliassen, assume a tank in which the flow is uniform but through the top third of the basin only (Figure 1A). Such a basin is functionally equivalent to an "ideal" basin of one-third the depth but otherwise identical (Fig-

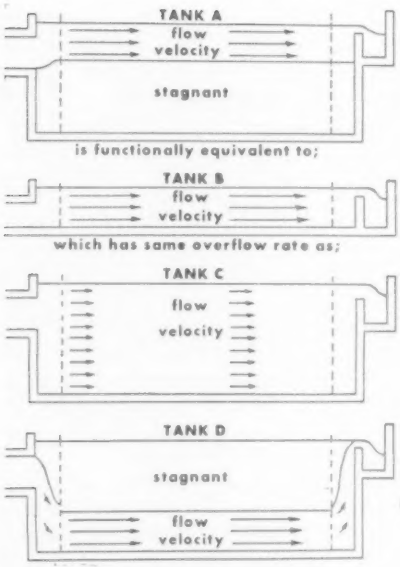


FIGURE 1.—Eliassen's demonstration.

ure 1B) because any particle settling to the bottom of the active upper one-third would be removed. That is, any particle which settles to the bottom of the active upper one-third would enter the stagnant lower two-thirds, through which it inevitably would settle to the bottom. Thus, the presence or thickness of stagnant layers would not affect removals and Tank B would neeessarily make the same removal as Tank A.

The demonstration becomes even more striking if a tank is assumed in which the flow is uniform but through the bottom third of the basin only (Figure 1D). It is clear that the stagnant, upper two-thirds would have no effect on sedimentation, and this tank also would make the same separation as the shallower ideal Tank B.

If it is true that removal is not a function of depth (Assertion I) then ideal Tank C, of the same dimensions as short-circuiting Tanks A or D, would make the same removal as the shallower ideal Tank B. It would, therefore, also make the same removal as Tank A or D. That is to say, a basin operating under ideal conditions (Tank C) would make exactly the same removal as an identical basin operating under extreme conditions of density-current short-circuiting. Therefore, if it is true that removal is not a function of depth (Assertion I), then it cannot be true that removal is decreased by such density-current short-circuiting; hence Assertion II cannot be generally true.

On the other hand, if density currents of the type exemplified should reduce removals for some type of suspension (Assertion II true for such suspensions), then it is possible that for such suspensions, tank depth and hence detention is a factor governing removal.

Eliassen's demonstration was countered (6) with the statement: "As commonly defined, overflow rate is the discharge per unit surface area of the tank. For the purpose of this discussion, the definition given by Stein is preferable—that is, overflow rate is equal to the ratio of depth to detention time. Since all particles of water do not have the same detention time, they do not have the same overflow rate. In other words, short-circuiting affects the overflow rate in precisely the same manner as it does the detention time."

This answer does not in any way resolve the dilemma presented by Eliassen's demonstration. First, no matter how overflow rate is defined, changing from ideal flow (Tank C) to an extreme type of short-circuiting (Tank A) would not change removals if it is true that removal is not a function of tank depth. Therefore, if Assertion I is generally true, Assertion II cannot be.

Second, it has been shown (4) for Class I suspensions that the "overflow rate" which governs removals is flow divided by the horizontal projected area across which the flow sweeps, regardless of flow depth or density-current short-circuiting. As thus de-

fined, overflow rate is obviously the same for basins A, B, and C. Of course, "overflow rate" can be defined arbitrarily in any chosen manner. However, if it is to be defined as tank depth divided by the detention time of the individual particles of water, then every water particle in the active flow of Tank A would have one-third the overflow rate of particles of water in Tank B because the individual detention times are identical and the depth of A is three times that of B. These two tanks, which it has been established give identical removals, would thus have "overflow rates" differing by a factor of three. Under such a definition, removal is clearly not governed by overflow rate alone, and Assertion I is invalidated.

Third, it does not seem logical to relate the removal from a particle of water traversing a basin to the function $\frac{\text{detention time}}{\text{tank depth}}$. What happens within any particle of water traversing the basin may be affected by its detention time, inasmuch as flocculation may be proceeding at a definite rate. It may be affected by the height of water above the particle, because solids are settling into it from the water above. However, within the context of the "ideal" tank behavior upon which the theories are based, it is not evident how the removal from a particle of water can be affected by the depth of water beneath it. Because total tank depth includes the depth beneath the particle of water, it is not logically apparent why the removal from this individual particle of water traversing the basin should be a function of total tank depth.

In any case, the dilemma still exists. If it be granted that removal is independent of depth, it must be allowed that it is also independent of density-current short-circuiting of the type exemplified. Where such density currents are harmful to removal, tank depth, and hence detention, must be a factor.

Eliassen was further answered (6):

"The literature is full of experimental evidence that short-circuiting impairs the removal of settling tanks. Nearly all the papers describing improvements made to inlets and the baffling of tanks reveal that the effect of such improvements was to increase the removal of suspended solids. These improvements have no effect on the ratio of discharge to surface area. The improvements must, therefore, have been caused by reduced short-circuiting."

This further answer also does nothing to resolve the dilemma presented by Eliassen's demonstration. It serves only to suggest that there is a weight of experience supporting one of the alternatives. It appears highly possible that removal from some kind of suspension will be a function of detention time *per se*.

The overflow rate principle has been largely accepted for the case of suspensions of the first class. This is particularly true in the field of metallurgical engineering, where sedimentation-type classifiers have long been designed (7) in accord with the findings of Hazen. The free-settling behavior of the discrete particles comprising a Class I suspension has been much investigated and is well established. The overflow rate principle was reaffirmed in an earlier study (4) for the case of suspensions exhibiting such particle dynamics. On the other hand, not much work seems to have been done on the mechanism of flocculation, and the postulates from which Camp derives his conclusions, although reasonable, seem not to have been subjected to experimental verification. Therefore, attention is directed to Class II suspensions and the mechanism of flocculation.

The Mechanism of Flocculation

Camp (2) ascribes flocculation in a sedimentation basin to two causes, as follows:

1. Differences in the settling velocity of particles, whereby faster settling

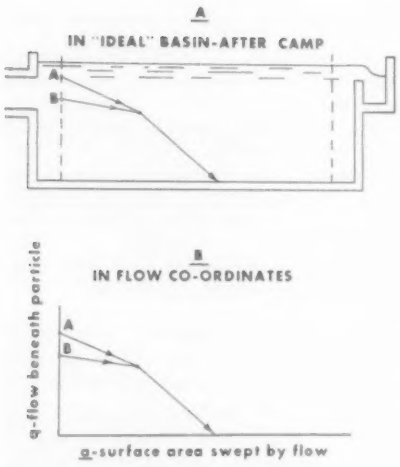


FIGURE 2.—Trajectories of agglomerating particles.

particles overtake those which settle more slowly and coalesce with them.

2. Velocity gradients in the liquid, which cause particles in a region of higher velocity to overtake those in adjacent stream paths moving at slower velocity.

He further states that: "In the ideal basin and in quiescent settling tests only the first cause is present." That is, of the two causes to which he ascribes flocculation, only differential settling would be active, because velocity gradients are absent by definition in the ideal basin and in quiescent settling.

Camp (3) analyzes flocculation in an ideal basin as follows: "For simplicity of illustration it has been assumed in Figure 2 (Figure 2 this paper also) that the tank velocity is the same throughout and that there is no turbulence. It may be seen now that if the depth is decreased for the same rate of discharge, the tank velocity V will be proportionately increased, and the slopes of the paths of the three particles will be proportionately decreased. Thus, particles A and B will coalesce at the same distance from the inlet end of the settling zone and the resulting larger particles will reach the bottom at the same distance from the inlet zone. It is evident, therefore, that flocculation due to differences in settling velocities of particles is not affected by the depth of the tank."

It is of interest that this same analysis will hold if the particle settling trajectories are transferred to a coordinate system such as earlier described (4). Here (Figure 2B) the vertical axis measures quantity of flow q passing below any given point, and the horizontal axis measures the cumulative horizontal projected area a across which the flow has swept. In such a coordinate system, it was shown that $q = va$, regardless of flow inclination or variation with depth, where v is the settling rate of a particle with respect to the surrounding fluid. The function $q = va$ is a straight line in this coordinate system as long as v is constant, having a slope determined by the value of v. Therefore, each particle before coalescence has a fixed linear trajectory, as does the resulting particle after coalescence.

The above reasoning appears necessarily valid for particles which collide, but there is a tacit assumption made. It is assumed that if particle A collides with particle B in a deep tank, it will also do so in a shallow one. However, particle A will be settling a greater distance in the deep tank and will sweep through a greater volume. Assuming identical concentration in the two cases, the probability that particle A will overtake and collide with some particle B is proportional to the volume swept by A. Therefore at a given overflow rate the probability of collision must be proportional to tank depth and hence to detention time. The tacit assumption appears not to be valid, and it is concluded that flocculation should be affected by tank depth. This is subject to experimental proof.

Earlier (4) the relationship between settling in Camp's ideal basin and

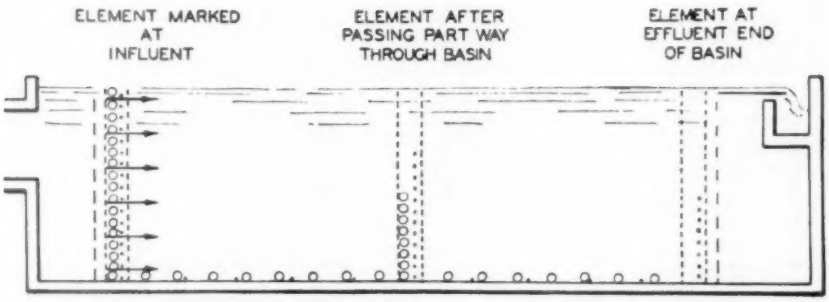


FIGURE 3.—Relationship between continuous and batch settling.

quiescent settling was discussed. As shown in Figure 3 the sedimentation taking place in an ideal basin would be indistinguishable from batch settling. If a vertical cylinder of feed suspension, extending from the top to the bottom of the basin, were marked at the influent end, it would maintain its shape and identity as it traversed the basin. This is the same as though a batch settling operation was moved sideways, which would have no effect on the relative motion of solid particles with respect to the suspending liquid. Therefore, a quiescent batch settling test should show the removals to be expected in an ideal basin. The time available for settling in the continuous ideal basin, which is the time available for settling in the cylindrical element of the flow or in an equivalent batch settling test, would equal the detention time in the basin. The depth to which the particle must settle to be removed would be the depth of the basin, which would be the same thing as the depth of the cylindrical element of flow or the depth in an equivalent batch test.

Overflow rate in the continuous ideal basin can be related to batch settling as follows:

$$v_o = \frac{q_s}{A} \quad \ldots\ldots\ldots\ldots (1)$$

in which v_o = overflow rate; q_s = total flow through basin; and A = projected area across which the flow sweeps.

But since Ah = basin volume,

$$\frac{Ah}{q_s} = t \quad \ldots\ldots\ldots\ldots (2a)$$

in which h = basin depth; and t = nominal basin detention time, or

$$A = \frac{tq_s}{h} \quad \ldots\ldots\ldots\ldots (2b)$$

Substituting in Eq. 1,

$$v_o = \frac{h}{t} \quad \ldots\ldots\ldots\ldots (3)$$

in basin. (Note that Eq. 3 represents the definition of overflow rate given by Stein. However, t here is defined through Eq. 2*a* as *nominal* basin detention time. It hence relates to the flow as a whole, rather than to the several detention times of individual droplets of water traversing the basin,

TABLE I.—Quiescent Settling Test Data, "Long Tube" Test No. 1

Time (min.)	Concentration (p.p.m.)			Average Removal (%)		
	1-Ft. Depth	3-Ft. Depth	5-Ft. Depth	1-Ft. Depth	3-Ft. Depth	5-Ft. Depth
0	393	393	393	0	0	0
15	393	387	387	0	0.5	0.9
30	379	381	383	3.8	3.6	3.3
45	307	353	341	28.7	19.6	16.4
60	177	207	271	56.4	53.2	47.6
90	90	117	113	80.4	75.6	73.5
120	52	75	72	89.3	85.2	83.5
180	21	47	48	96.9	93.1	90.8

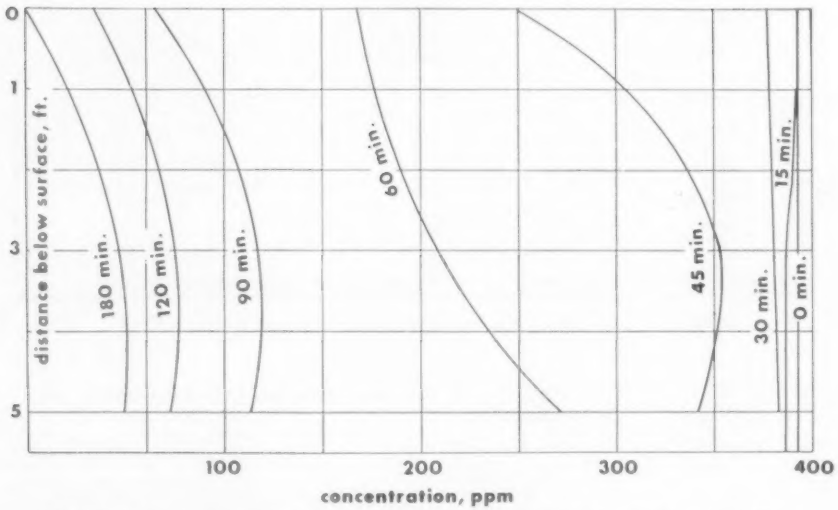


FIGURE 4.—Concentration profiles in batch settling test, "long tube" test No. 1.

and would not be altered by short-circuiting.)

Now if removal in an ideal continuous basin is governed by overflow rate, then it is governed by the equivalent ratio h/t. As has been demonstrated, the removal in quiescent batch sedimentation should be governed by the same ratio h/t. Therefore, in a batch test the locus of a zone of constant concentration should move downward, at a constant rate equal to h/t. Experimentally, when flocculation takes place, this is not at all true. Therefore, removal must be governed by something other than overflow rate alone.

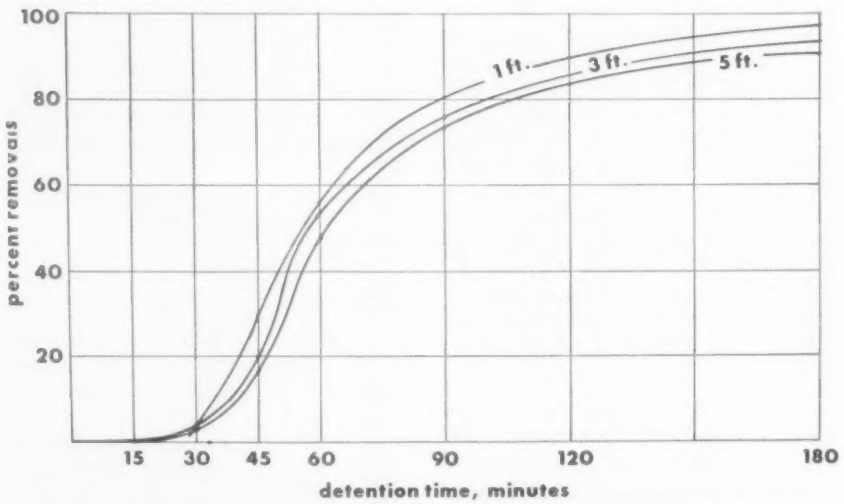


FIGURE 5.—Per cent removals as function of detention, quiescent settling test, "long tube" test No. 1.

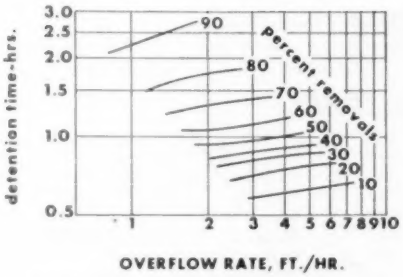


FIGURE 6.—Relationship between detention and overflow rate, "ideal" basin, "long tube" test No. 1.

Camp (2) describes a method for carrying out a batch settling test, in which samples are taken at a series of depths and times from a quiescent settling column. He gives illustrative data which show clearly that concentration is not governed by h/t when flocculation is taking place, but unfortunately the data are stated to be hypothetical. Because it is important to discover by how much the postulated mechanism of flocculation is in error, calculations were made from some available "long tube" test data. The test material in this case was whiting ($CaCO_3$) suspended in water. The vessel or tube was sampled at 1 ft., 3 ft., and 5 ft. below the surface after various times of quiescent settling. The data are presented in Table I.

From the data of Table I concentration profiles, showing concentration as a function of depth in the settling vessel, are plotted for each value of time (Figure 4). From these concentration profiles are calculated the average per cent solids above each of the sampling points at each of the sampling times. This gives the average concentration of solids that would be present in the corresponding overflow from an ideal basin.

The average overflow concentrations are recalculated as per cent of the original solids removed from the overflow in each case. Curves are plotted (Figure 5) showing per cent removal as a function of detention time for each of the sampling depths.

Values of detention for fixed values of per cent removal are read from Figure 5 for each of the sampling depths. The corresponding overflow rate (namely, sampling depth/detention time) is calculated for each. These data are shown in Table II, and are plotted on log-log scales in Figure 6.

Figure 6 now shows the relationship between detention time and overflow rate which would be predicted for an "ideal" basin on the basis of a strictly equivalent quiescent settling test. If removals were governed by overflow rate and were independent of detention, the curves for various values of "per cent removal" parameter should be vertical. If removals were governed by detention time alone, they should be

TABLE II.—Detention vs. Overflow Rate at Fixed Value of Removal as Parameter, "Long Tube" Test No. 1

Removal (%)	1-Ft. Depth		3-Ft. Depth		5-Ft. Depth	
	Detention (min.)	Overflow Rate (ft./hr.)	Detention (min.)	Overflow Rate (ft./hr.)	Detention (min.)	Overflow Rate (ft./hr.)
10	35	2.86	38	4.74	40	7.5
20	41	2.44	45	4.0	47	6.9
30	46	2.18	50	3.6	52	5.76
40	50	2.0	53	3.4	56	5.35
50	56	1.79	58	3.1	62	4.84
60	63	1.59	66	2.72	71	4.22
70	73	1.37	80	2.25	84	3.57
80	89	1.12	102	1.77	108	2.78
90	123	0.81	145	1.24	165	1.82

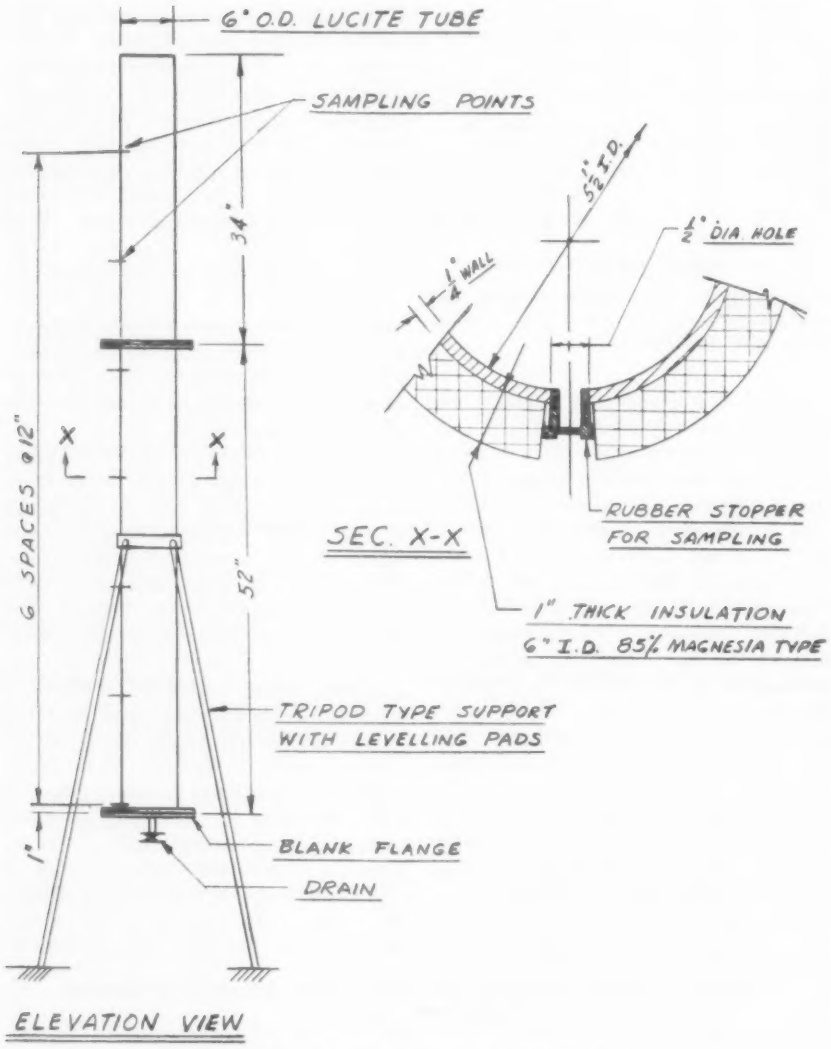


FIGURE 7.—Details of quiescent settling column.

horizontal. It will be seen that they are neither. However, they are more nearly horizontal than vertical. Removals of this material in an ideal basin would be governed more by detention time than by overflow rate.

The quiescent settling test previously described is representative of a large number of such tests made on many different materials. The concentration profiles, however, are determined from samples at three depths only. To obtain a more accurate delineation of concentration profiles, a special test was run.

The experimental apparatus is shown in Figure 7. It consisted of an insulated lucite tube 5½ in. in internal

TABLE III.—Data of "Long Tube" Test No. 2 *

t_1 = 0 hr.†		t_2 = 0.25 hr.		t_3 = 0.50 hr.		t_4 = 1.0 hr.	
h	c	h	c	h	c	h	c
0.31	361	0.30	308	0.25	180	0.21	156
3.31	399	1.30	381	1.25	312	1.21	186
6.31	408	2.30	385	2.25	333	2.21	183
—	—	3.30	386	3.25	362	3.21	191
—	—	4.30	394	4.25	370	4.21	184
—	—	5.30	396	5.25	377	5.21	189
—	—	6.30	415	6.25	374	6.21	196

t_5 = 2.0 hr.		t_6 = 4.0 hr.		t_7 = 7.5 hr.		t_8 = 24 hr.	
h	c	h	c	h	c	h	c
0.17	82	0.12	60	0.09	48	0.04	38
1.17	88	1.12	63	1.09	48	1.04	41
2.17	95	2.12	71	2.09	51	2.04	42
3.17	95	3.12	76	3.09	51	3.04	43
4.17	101	4.12	70	4.09	51	4.04	45
5.17	108	5.12	76	5.09	57	5.04	46
6.17	105	6.12	77	6.09	59	6.04	44

* h = distance below surface, in feet; c = concentration, in p.p.m.
† Samples taken as soon as possible.

diameter and 7 ft. tall. At 1-ft. intervals down the side of the tube were holes in which fitted the type of rubber stopper used in serum bottles. These permitted sampling by means of a veterinary hypodermic needle and syringe, the stoppers sealing themselves after withdrawal of the needle. The test material was again whiting suspended in water, with 15 p.p.m. of Ferrisul added just before the start of the sedimentation test as a coagulant. Samples taken at various times through the serum stoppers were acidified to dissolve the suspended $CaCO_3$, and then titrated by the Versenate method. The concentration thus determined was corrected on the basis of a blank titration made on the water. The absolute accuracy of the analytical method was not believed to be high in the range of sample size and concentration used, but was believed to have a relative accuracy sufficient for the test purpose.

The data obtained in this second "long tube" test are presented in Table III, and the resulting concentration profiles after various sedimentation times are shown in Figure 8. Using the same procedure as described for the first test, a plot was prepared of overflow rate vs. detention time for various fixed values of removal as parameter. This is shown in Figure 9. In both Figure 8 and Figure 9 the data are plotted without smoothing.

As in the first test, the curves of Figure 9 are more nearly horizontal than vertical, indicating that detention again plays a more important role than overflow rate in determining the removal of suspended solids from this Class II suspension.

Conclusions

The published settling theory which leads to the conclusion that removal should always be governed by overflow rate and be independent of depth, leads also to conclusions demonstrably contrary to experience and experimental fact. It would be imprudent to discard detention time as a design factor on the basis of this theory.

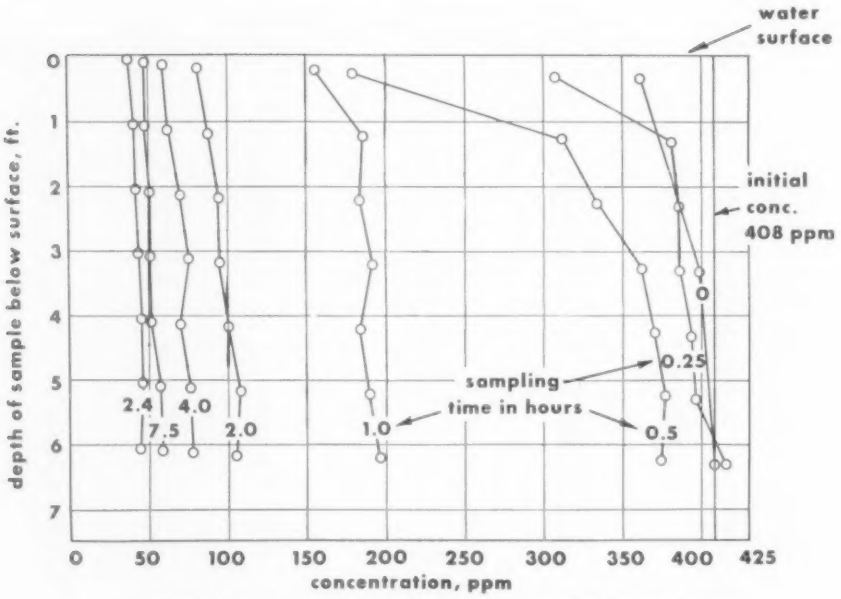


FIGURE 8.—Concentration profiles, "Long tube" test No. 2.

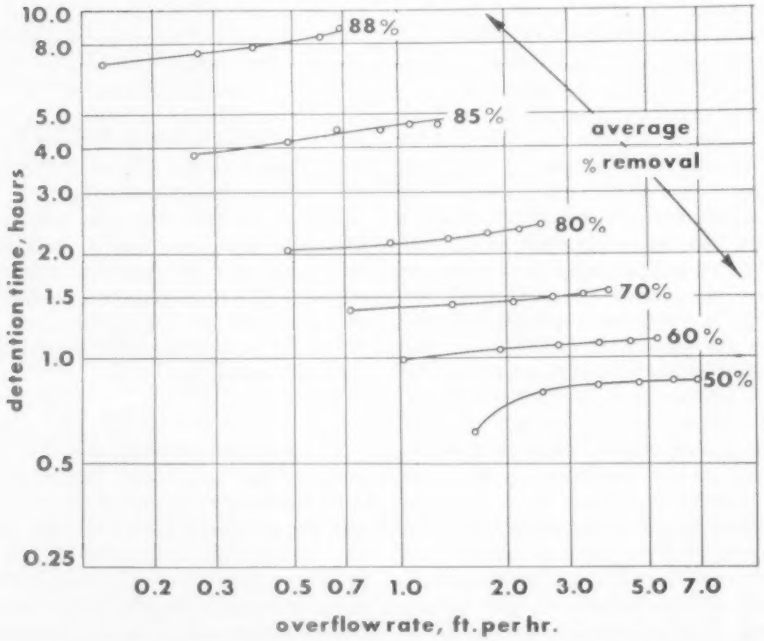


FIGURE 9.—Relationship between detention and overflow rate, "Long tube" test No. 2.

There is evidence that for settling Class II suspensions, in which particles continue to coagulate or flocculate during the sedimentation period, detention time can be of considerably greater significance than overflow rate.

Acknowledgment

Sincere appreciation is expressed to R. H. Van Note for the data presented as "long tube" test No. 1, and to Fred C. Ebetsch for carrying out "long tube" test No. 2.

References

1. Hazen, A., "On Sedimentation." *Trans. Amer. Soc. Civil Eng.*, **53**, 45 (1904).
2. Camp, T. R., "Sedimentation and the Design of Settling Tanks." *Trans. Amer. Soc. Civil Eng.*, **111**, 895 (1946).
3. Camp, T. R., "Sedimentation Basin Design." THIS JOURNAL, **25**, 1, 1 (Jan., 1953).
4. Fitch, E. B., "Flow Path Effect on Sedimentation." THIS JOURNAL, **28**, 1, 1 (Jan., 1956).
5. Eliassen, R., "Sedimentation and the Design of Settling Tanks—Discussion." *Trans. Amer. Soc. Civil Eng.*, **111**, 947 (1946).
6. Camp, T. R., "Sedimentation and the Design of Settling Tanks—Discussion." *Trans. Amer. Soc. Civil Eng.*, **111**, 952 (1946).
7. Roberts, E. J., and Fitch, E. B., "Predicting Size Distribution in Classifier Products." *Mining Engrg.* **8**, 11, 113 (Nov., 1956).

PRESIDENT WATSON TO BE HONORED

The Capital District Section, New York Sewage and Industrial Wastes Association, is planning for its fall function a dinner dance in honor of Federation President Kenneth S. Watson. The event will be held at the Van Curler Hotel, Schenectady, N. Y., on October 26.

A cordial invitation is extended by the Section to all the friends of President Watson to attend this affair. Information may be obtained from Pat Ferrucci, Bureau of Sewage Treatment, City Hall, Schenectady, N. Y. Dinner bids are $4.50 per person and should be obtained immediately. Make checks or money orders payable to the Capital District Section, NYSIWA.

PLANNED WATER RECLAMATION *

By A M Rawn and F. R. Bowerman

Chief Engineer and General Manager, and Division Engineer, respectively, County Sanitation Districts of Los Angeles County, Los Angeles, Calif.

Reclaiming water from sewage is surprisingly like finding a long-lost ten-dollar bill. In both cases one recovers something that has formerly been lost and considered beyond recovery; in neither case does one actually create new wealth. This is a concept that has sometimes been overlooked in the controversy that views water reclamation in the light of its possible competition with the importation of surface water supplies. In a very real sense, there is no competition between the transportation of excess surface waters from a water surplus area to a water deficient area and the idea of re-using certain wasted waters which are amenable to reclamation. The latter is more in the order of a practicing of thrift, in that one does not increase income by decreasing waste, yet the end result is an improvement in over-all economic welfare.

It has been stated quite correctly that water is one of the few unchanging commodities in the world. The last glass of water you drank might well have contained the same molecules of water that first were separated from the land to form the oceans, next quenched the thirst of some prehistoric monster, and later, conveyed the royal barge of Cleopatra along the stretches of the Nile. Reasoning thus, it is quite apparent that man neither creates nor destroys water, but is merely afforded an "in transit" use of the water as it crosses the land on its way to the oceans.

In semi-arid climates, such as both bless and distress Southern California, the utility of surface water and ground water has been carefully engineered to a high degree of efficiency. The Flood Control District of Los Angeles County, serving in the dual capacity of flood control and water conservation, has managed to retain some 85 per cent of the flood waters that, in years past, would have reached the ocean. These conserved waters are percolated into the ground, thereby serving to reduce somewhat the overdraft on underground supplies. Another major source of water suitable for similar conservation and restoration to the underground is now wasting to the ocean through sewers.

This paper is designed, in part, to explore the possibility of reducing the overdraft on ground-water basins underlying the alluvial plains bordering the Pacific Ocean by reducing the wastage of water to the ocean. The situation as it now exists may be thought of as a siphoning of the ground-water basins by sewer systems discharging to the ocean; the possibility of intercepting this flow and reclaiming some of the water is basic to a program of water conservation in Los Angeles County or in any coastal area where similar conditions exist.

Definition

Much water reclamation occurs without planning—the hydrologic cycle of evaporation and rainfall is one example; the use of cesspools and septic tanks another; the discharge of a sewage treatment plant effluent to a river,

* Presented at the 1957 Annual Meeting, California Sewage and Industrial Wastes Assn.; San Diego, Calif.; May 1–4, 1957.

stream, or to other disposal, still a third. Planned water reclamation requires that the engineered intent of the process is to reclaim for re-use a water that would otherwise be wasted. Recent surveys by the University of Southern California in conducting a research project for the California State Water Pollution Control Board have disclosed many such planned water reclamation schemes presently employed throughout the arid and semi-arid areas of southwestern United States. These include irrigational, recreational, and industral re-uses, as well as some involving recharge for groundwater replenishment. The economic study of many of these planned water reclamation projects reveals substantial savings, because alternative water supplies are either very costly or nonexistent. The economy of planned water reclamation may not be so apparent in areas where large-scale importation of water might appear to suffice for any and all water needs; this latter requires further elucidation.

The transporting of water from the High Sierras across the 233 miles that lie between the Owens Valley and Los Angeles and the conveying of Colorado River water by means of pipeline and aqueduct over some 242 miles of desert waste lands to the Los Angeles and San Diego metropolitan areas are engineering feats that beggar description. The proposed importation of water from the Feather River to Southern California proves that the pioneer spirit of our predecessors remains active in the hearts and minds of today's engineers. The recapture of wasted waters may seem inconsequential when observed against the backdrop of such enormous engineering achievements, but here it must again be noted that the process described as planned water reclamation is not competitive with the aforementioned water supply systems. What can be accomplished, at best, is merely to plug some of the leaks in the ground-water basins which are occasioned through use of the ocean as a prime means of disposal for sewage effluents.

Ocean Disposal—Mixed Blessing

The disposal of sewage effluent to the ocean holds a mixed blessing. To industry, the ocean disposal of trade wastes affords an answer to what might otherwise be an almost insolvable problem. The addition of mineral constituents to sewage through domestic use is nominal and scarcely changes the chemical nature of the water recovered from such wastes. On the other hand, industries waste generous quantities of soluble chemicals which cannot be removed by known sewage treatment processes; reclaimed water from such sources, if introduced to the ground for recharge, would render unusable for general domestic purposes those valued ground waters with which it would mingle.

The alternative separation of such chemical wastes from the common sewer and their separate conveyance by truck or otherwise to points of land disposal would render many industrial processes much too expensive to permit their competition with other industries located in areas where the ground-water supplies were not endangered and costs for disposal were lower. To be sure, certain highly concentrated or toxic chemicals are now prohibited from discharge to the sewer to insure the safety of maintenance personnel and to avoid upsetting biological processes at sewage treatment plants; however, these amount to but a small portion of the total wastage of industrial chemicals. As an example, the estimated volume of industrial wastes discharging to the system of the Los Angeles County Sanitation Districts (serving about 2,750,000 people) is some 38,000,000 gal. daily. Some of these wastes are relatively innocuous such as the blowdown from cooling towers, rinses, and the like; however, the greatest portion of such waste com-

prises mineralized discharges which would make quite difficult, if not impossible, the recovery of a water suitable for introduction to ground-water basins.

As compared with this estimated 38,000,000 gal. daily of industrial discharge to the sewer, there are an additional estimated 60,000 gal. daily of concentrated sulfuric, chromic, nitric, hydrofluoric, and other such concentrated chemical wastes which are conveyed by tank truck to the only three known sites suitable for the disposal of such wastes within a distance of 30 miles of the Los Angeles Metropolitan area or else barged to sea for disposal far from the coastline. It can be seen quite clearly that the sewer must be the principal recipient of mineralized industrial wastes; thus, the advantage of having a terminal disposal facility such that it discharges to an already highly mineralized ocean is of incalculable financial advantage to industry. These advantages quite naturally are reflected in the records of the Chamber of Commerce, which show the Los Angeles Metropolitan area to be one of the most rapidly expanding areas in the United States.

With the ocean affording ready and inexpensive disposal for chemical wastes, one might logically question the earlier statement that ocean disposal is a mixed blessing. The disadvantage of ocean disposal is that it places beyond economic recovery the wastes that are discharged to the ocean. Much of the sewage flowing in large sewerage systems such as the Los Angeles City and Los Angeles County Sanitation Districts systems is suitable for recovery and re-use, provided it is intercepted and extracted from the system soon enough to avoid its mingling with mineralized industrial wastes. Once domestic sewage has mixed with highly saline brines from oil fields or caustic discharges from metal working plants or the neutralized acid wastes from refineries, aircraft or metal finishing plants, there is little more that can be done with it than to treat the organic constituents to prevent nuisance and to protect public health, and discharge the treated effluent to the ocean.

Perhaps, at this point, it might be well to reflect momentarily on the economies of ocean disposal as compared with the treatment and disposal of sewage effluents inland. In extended systems (for example, the main trunk sewers of the Los Angeles County Sanitation Districts reach for distances up to 50 miles) the cost for collecting and conveying wastes over such distances may equal or exceed the greater treatment costs required for inshore disposal. Since the capacity of the ocean for accepting sewage effluent in any given area is not without limit, there is reached an optimum point at which the construction and operation of inland sewage treatment plants becomes a more economical process than the construction of long trunk sewers and sewage treatment plants having ocean disposal. In Los Angeles County, this optimum point is rapidly being reached and before long, or perhaps even now, the construction of sewage treatment plants in the upper valleys may hold economic advantage over ocean disposal.

Los Angeles Metropolitan Area

Fortunately, normal community growth in the Los Angeles Metropolitan area has resulted in the locating of industrial centers on the alluvial plains near the ocean, while upper foothill areas have largely developed as residential communities. This will probably be true of most such coastal areas, since rail routes and major highways generally thread their way along the flatter coastal plains and these are the arteries on which modern merchandising depends; conditions in the Los Angeles Metropolitan area may not be too dissimilar from those to be encountered in other coastal metropolitan areas.

The sewage flowing from residential communities is readily amenable to recovery for re-use and only requires the planned establishment of water reclamation plants strategically located so as to have available a constant supply of residential sewage.

Water Reclamation Works

Location

The phraseology "only requires" may lull one into a false sense of simplicity in the establishing of water reclamation plants since public resistance to the location of sewage treatment plants may be substantial. For this reason, locations must be chosen which utilize such natural buffering as is afforded by parks, flood control channels, freeways, manufacturing areas and similar non-residential developments. A case in point would be the locating of a sewage treatment plant in the impounding area behind the Whittier Narrows Dam in Los Angeles County. Flooding behind the dam may eventually inundate as many as 2,350 acres, from which homes and businesses have already been removed. An oil refinery and oil and water wells, adequately protected by earth levees, will remain within the predicted flood zone and it seems quite logical to assume that a sewage treatment plant located therein could likewise be protected. A major recreational area with fish ponds and other park facilities is already under development and any or all of these facilities could readily be serviced with reclaimed sewage effluent if it were so desired.

Spreading Basins

Perhaps a more practical use of reclaimed sewage effluent at the Whittier Narrows might be the recharge of such waters to the ground-water through spreading basins already existing along the Rio Hondo Channel about three miles below the Whittier Narrows outlet works. These spreading grounds at present operate about two months yearly, restoring rainwater to the groundwater reservoir through controlled release of impounded flood waters captured in multiple purpose reservoirs in the San Gabriel Mountains. The utility of these already existing recharge basins could be extended to the entire 12-month period through the operation of a sewage treatment plant above the Whittier Narrows which would supply continuously the necessary water for spreading.

Economics

The economy of reclaimed water cannot logically be compared with the cost of water pumped from the ground, since the possibility is extremely remote that water for spreading purposes would ever be derived from a groundwater source. In general, ground water basins in a large metropolitan area will probably all be depleted to some degree and it is difficult to imagine a condition wherein water would be extracted from a basin having surplus waters and delivered by pipeline to a recharge area overlying a basin having a ground-water shortage. The three sources of water suitable for groundwater replenishment are: runoff water, resulting from rainfall; imported water; and water reclaimed from sewage. Runoff in Los Angeles County is now being conserved to about the optimum economic level; additional capture of runoff would necessitate the building of impounding dams and reservoirs at great cost for but little increase in the amount of runoff conserved. The availability of impounded runoff is a natural corollary to the operation of flood control works and, while not merely incidental to protection from floods, costs for providing storage and controlled release are but a minor part of the cost for flood protection.

It has been predicated that the reclamation of water from sewage is not competitive with the importation of surface waters and this is true in the

realm of quantity and quality, but not in cost. Imported waters are available for almost any and all purposes, including direct domestic use, and usually in sufficient supply to serve major users. Reclaimed waste waters are, generally speaking, available in limited supply, at specific locations, and can be used only for specific purposes, excepting re-use which occurs subsequent to percolation and return to a ground-water basin, at which time the water may again be used for any and all purposes. The compelling reasons for reclaiming waste water exist in the need for conserving ground-water supplies and restoring ground-water tables, and in the cheaper cost of providing water for ground-water replenishment through the reclaiming of sewage. Whereas the over-all cost of imported Colorado River water is in the order of $42.00 per acre-ft., it is quite feasible to provide a water reclaimed from sewage through the activated sludge sewage treatment process for considerably less than one-half of this cost.

Of considerable importance is the fact that the raw water supply, *i.e.*, sewage, is now present and available, while the availability of greatly increased quantities of imported waters, such as from the Feather River, will depend upon more than a decade of planning and construction. The existence of a substantial, steady supply of low-cost water suitable for industrial, recreational, and ground-water recharge purposes is indisputable. The present time appears to be not any too soon to make use of such waters as a means of reducing the serious overdraft on the valued ground-water reservoirs.

POSITION AVAILABLE

New York State Department of Health—Positions available in all phases of sanitary engineering. Bachelor's degree in sanitary, public health, civil or chemical engineering required. Positions available are:

Junior Engineer—	$5,246–$6,150
Assistant Engineer—	$6,140–$7,490
Senior Engineer—	$7,500–$9,090

Information may be obtained from the Office of Personnel Administration, New York State Department of Health, 84 Holland Ave., Albany 8, N. Y.

WATER RECLAMATION EXPERIMENTS AT HYPERION *

By H. A. van der Goot †

Supervising Civil Engineer, Los Angeles County Flood Control District, Los Angeles, Calif.

This paper will present a progress report on water reclamation experiments being conducted by the Los Angeles County Flood Control District at the Hyperion Treatment Plant of the City of Los Angeles.

In Los Angeles County the water supply is composed of nearly 60 per cent local water, most of which is pumped. Of the pumped water, approximately 35 per cent, some 210,000 acre-ft. per year, represents overdraft on the ground-water basins. Alleviation of this overdraft through use of imported Colorado River water and, in the future, Feather River water, is an idea familiar to most people informed on California water plans.

The reclamation and re-use of sewage treatment plant effluent is another potential supply for alleviation of this overdraft, particularly in the coastal areas of Los Angeles County where wastage to the ocean from the two major collection systems now amounts to approximately 485,000 acre-ft. per year. If allowed to continue to increase at the present rate, this waste will outstrip imported water supplies before Feather River water becomes available.

The Flood Control District has been studying the practicability of waste water reclamation and conservation since 1948. Three waste water reclamation field tests have been conducted by the District—one in 1948 at Whittier, Calif., another in 1949 in Azusa, Calif., and since 1955 one on a site adjacent to the Los Angeles Hyperion Treatment Plant. From these tests it appears that ground-water replenishment with reclaimed water is feasible, but that each application presents a different situation with respect to percolation rates, permissible organic loading, and operational procedures. In the way of an introduction to the tests at Hyperion, a summary of the previous tests at Whittier and Azusa is pertinent.

Whittier and Azusa Tests

The objectives of the tests at Whittier and Azusa were to determine (a) whether ground-water pollution was a problem in causing sewage treatment plant effluents to percolate from spreading ground areas, and (b) the rates of infiltration which could be expected using such effluents. In particular, it was desired to obtain samples of the percolating waters above the ground-water level in order to determine the quality of water entering the saturated aquifers.

At Whittier a small test spreading basin (Figure 1) was constructed along with sampling pans located at depths from 4 to 7 ft. below the basin surface. Soil at Whittier was a relatively fine, sandy loam. The inflow to the basin came from the Whittier sewage treatment plant, which utilized the trickling filter process.

At Azusa, the trickling filter effluent of the Azusa sewage treatment plant was tested in a new percolating basin (Figure 2), similar to those which had been in use for many years for disposal

* Presented at the 1957 Annual Meeting, California Sewage and Industrial Wastes Assn.; San Diego, Calif.; May 1–4, 1957.

† Deceased June 21, 1957.

FIGURE 1.—Test sewage spreading area at Whittier, Calif.

of the plant effluent. In contrast to the relatively fine soils at Whittier, the soil at Azusa is quite coarse and permeable.

For these tests, plant effluents were run into the test basins at rates to sustain a 0.5- to 1.0-ft. depth of fluid in the basins for a period of one week at Whittier and seven weeks at Azusa. The average B.O.D. value and suspended solids content of the plant effluent (spreading influent) were 7 p.p.m. and 51 p.p.m., respectively, at Whittier, and about 30 p.p.m. and 61 p.p.m., respectively, at Azusa.

It was concluded from these tests that no significant bacterial contamination would occur below a depth of 7 ft., providing spreading rates on coarse soils, such as were encountered at Azusa, were limited to 1 ft. in depth per day and the B.O.D. did not exceed 30 p.p.m. (The medium values of coliform bacteria in the 7-ft. pan at Azusa was 0.23 M.P.N. per milliliter.) These factors were proven valid by spreading runs of several weeks duration.

Hyperion Test

The planning, for an 11-mile freshwater barrier to prevent sea water in-

FIGURE 2.—Percolation basins at the Azusa, Calif., sewage treatment plant.

trusion along the Santa Monica Bay coast line of Los Angeles County, includes the necessity of providing a large, inexpensive water supply. One of the possible sources for this water is the effluent of the Hyperion sewage treatment plant which, at present, is a high-rate activated-sludge process. Recharge wells supplied by pipe line would be used to form the fresh-water barrier.

Tests to determine the practicability and the economic feasibility of reclaiming this waste water were started in 1955. Initially, it was visualized that reclamation would include: (*a*) the surface spreading of the plant effluent into a shallow, dry ground-water reservoir; (b) the recapture of this spread water by pumping; and (c) the distribution of pumped water by pipe line to the line of recharge wells. The required reclamation treatment was to be provided by the spreading techniques previously tested at Whittier and Azusa and would have required a large, contiguous acreage of permeable sand dunes. It was expected that some differences in the quality of the effluent would be encountered in this test as compared to the Whittier and Azusa tests, because there were differences in character of the treatment plants. Furthermore, the dune sands at Hyperion are very permeable and of uniform character compared with the soil at the other test sites.

Spreading Basins

For the Hyperion tests, two 0.5-acre spreading basins were constructed on sand dune hills south of the treatment plant (Figure 3). The schematic layout of the facility is shown in Figure 4. A pump station was installed to supply plant effluent to the test site, and drains from the spreading basins were installed to collect the test effluent for purposes of water quality testing and disposal back into the plant effluent system.

The basin beds consisted of native, wind-blown dune sand 13 ft. in depth having an exceptionally uniform grain size. The bottom of the beds was given an impermeable lining to facilitate collection of the percolated waters and sampling pans were placed within the basin soils at the 3-, 5-, 7- and 10-ft. levels. Later, a basin of approximately 3 acre-ft. capacity was constructed to provide storage to even out the quality of the plant effluent and to provide some additional treatment by settling and oxidation.

After the test had proceeded to the point where the quality of the test effluent was satisfactory, a recharge well and three observation wells were drilled in the plant area. These wells intercepted a confined aquifer with a water surface elevation about 2 ft. below sea level. The water had a chloride concentration of 14,000 p.p.m., indicating almost complete degradation

FIGURE 3.—Sand dune spreading basin area, Hyperion sewage reclamation test.

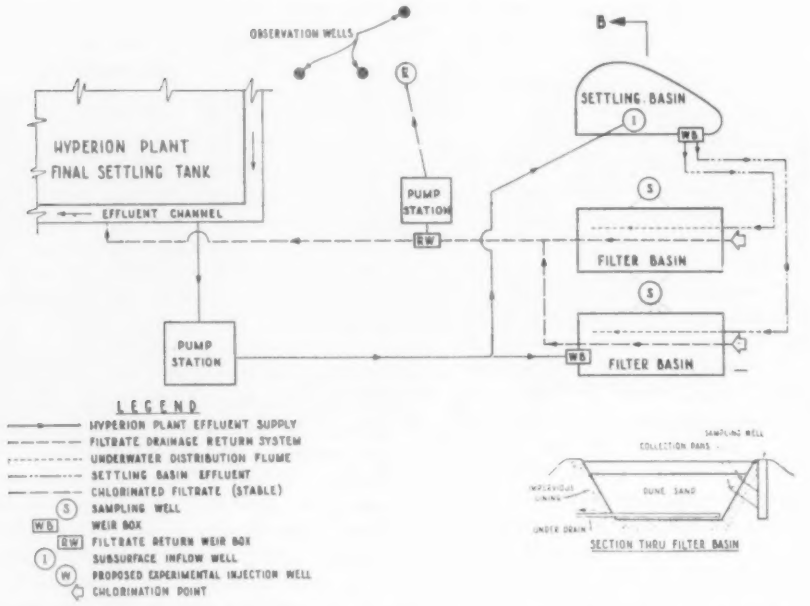


FIGURE 4.—Schematic flow diagram of the waste-water reclamation test facilities at Hyperion.

by intruding sea water. The recharge well was constructed with an 8-in. casing and gravel-packed to a total diameter of about 15 in. A 400-lb. per day chlorinating unit was installed to treat the water before injection in the well. In addition to these main test items, lysimeters were constructed from lengths of 5-ft. corrugated pipe by setting one end on a concrete base and filling with various depths of sand. The lysimeters were used for various special tests and for trial testing of new methods prior to basin spreading.

Testing

Testing was conducted in three phases, beginning with the determination of the characteristics of the treated effluent from the plant and the spreading medium, followed by improvements in the method of spreading, and leading to injection of the treated effluent through a recharge well. Initially, the basins were spread on a continuous basis for a period of approximately six months. This method provided a relatively good quality water but at very low rates. The results were comparable with previous water reclamation tests and water spreading experience.

During the next stage, attempts were made to increase the percolation rate of the basins by raking. Raking in one case was done after the basin had been dried and in another case while the basin remained ponded. This procedure provided a fairly good quality of water, as well as practical spreading rates. However, after a period of several months a deterioration in the quality of the basin effluents indicated the build-up of anaerobic conditions within the basin beds with a resultant formation of sulfides.

To alleviate this condition by the introduction of more air into the basin beds, a program of intermittent spreading was initiated. Intermittent spreading, in this instance, was accomplished

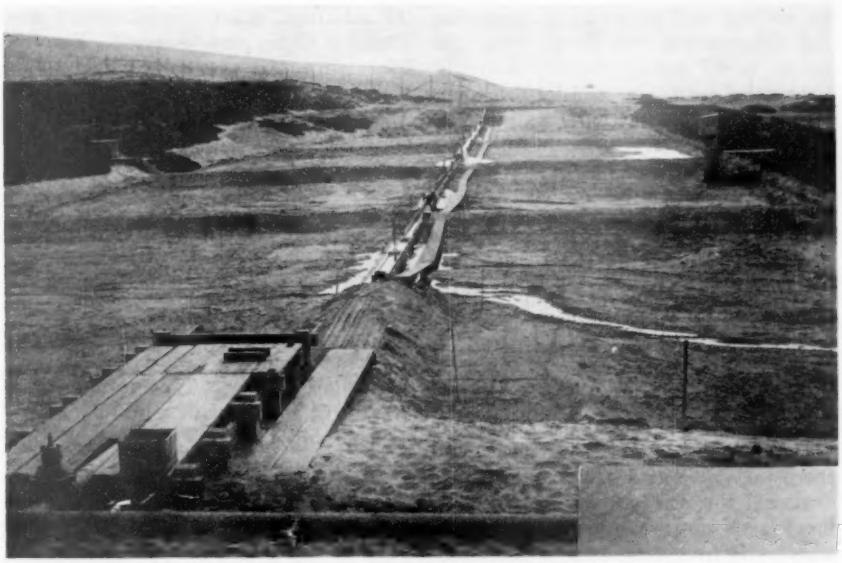


FIGURE 5.—Distribution flume and sub-basins in filter basin No. 2.

by dividing each basin into eight sub-basins (Figure 5). A given volume of water was introduced, consecutively, into each sub-basin for 30 min. each day, thereby providing time for percolation of the introduced water and basin drying during the remainder of the day. To date the volume spread has been the equivalent of 0.5 c.f.s. per acre; or 1-ft. per day over the basin area. Later, tests may be run with more frequent spreading and at higher rates. The results of this type of spreading were excellent, yielding a high-quality, sparkling clear effluent (Table I). The success of intermittent spreading compared with continuous spreading apparently is related to the maintenance of aerobic conditions in the basin beds.

Beginning in July, 1956, effluent from the test basins has been chlorinated and injected into the aquifer through the test recharge well. Several problems were encountered during the first injection well runs including: (a) an apparent inadequacy of area of perforations and underdevelopment of the recharge well; (b) the injection of a test effluent with too high a B.O.D. content and suspended solids concentration; and (c) the deposition of corrosion products in the perforations of the recharge well or in the aquifer immediately adjacent to the well.

Encouraging results were obtained when these difficulties were remedied by rehabilitation of the recharge well

TABLE I.—Results of Basin Spreading

Item	Continuous Spreading		Intermittent Spreading
	Without Raking	With Raking	
Percolation rate (c.f.s./w.a.)	0.15	1.0	0.5
B.O.D. (p.p.m.):			
Basin influent	35	42	31
Basin effluent	7	7	2
Reduction (%)	80	83	93
Suspended solids (p.p.m.):			
Basin influent	38	71	55
Basin effluent	4	15	11
Reduction (%)	89	79	80

by bailing and surging; by reducing the chlorination rate from about 20 p.p.m. to 0.7 p.p.m., thereby lowering the rate of corrosion; and by the introduction of effluent from the intermittent spreading method. With these remedies, a well run has continued for 127 days with an injection head not exceeding 46 ft. During this well run, the B.O.D. of the injected water averaged 1.5 p.p.m. and the suspended solids content averaged 13 p.p.m. Chlorination to a residual of 0.1 p.p.m. has been effective in maintaining a water which meets United States Public Health Service drinking water standards for coliform bacteria.

During the course of the tests, there were several developments which changed the over-all objectives. A large area of dune sand, which had tentatively been chosen for reclamation spreading, was taken over by the Los Angeles International Airport to be used in a manner incompatible with spreading requirements. In addition, the growing overload of the Hyperion treatment plant was cause for development of expansion plans, which will modify the treatment plant processes. It has been indicated that after modification the secondary facilities of the treatment plant will be utilized for standard-rate activated sludge treatment of a portion of the plant effluent. Since, under these circumstances a more highly treated water might be available for water reclamation, the tests were directed to the development of an adequate, economical "polishing" treatment for standard-rate effluent.

In order to determine what treatment would be necessary before injection of the effluent into a recharge well, a pilot plant was set up in the Hyperion plant area to yield a standard-rate effluent for test purposes. It is planned to test the following processes to determine their applicability to the required polishing treatment: (a) trickling filter with subsequent sedimentation; (b) rapid sand filter, and (c) intermittent high-rate spreading. In addition, other manufactured mechanical filters may be tested. Finally, direct injection of a chlorinated standard-rate activated sludge effluent into the recharge well may be tested provided the effluent quality permits.

Conclusions

The tests at Hyperion have shown that water suitable for injection through a recharge well can be obtained from reclamation of a high-rate activated sludge effluent through controlled spreading. Still to be determined are the best type of polishing treatment to use with a standard-rate effluent and the costs which might be expected for such treatment. To bring the Hyperion tests to a successful conclusion, it will be necessary to show that reclaimed water of a sufficiently high quality for recharge purposes can be provided at a cost comparable to that of alternate supplies of imported water.

Acknowledgments

The full cooperation of the City of Los Angeles' Board of Public Works in permitting use of Hyperion plant areas, providing power for pumping, analyzing many samples, and furnishing technical information is sincerely appreciated. The assistance of the staff of the Hyperion Treatment Plant, particularly G. A. Parkes, Chief Engineer; R. D. Bargman, Assistant Chief Engineer; W. F. Garber, Laboratory Director; and J. M. Betz, Senior Civil Engineer, proved most helpful.

The tests were directed by H. E. Hedger, Chief Engineer, Paul Baumann, Assistant Chief Engineer in charge of the Dams and Conservation Branch, and Finley B. Laverty, Chief Hydraulic Engineer, all of the Los Angeles County Flood Control District.

The author is indebted to Mr. Laverty for his review and valuable suggestions, and to A. E. Bruington, Civil Engineer, Los Angeles Flood Control District, for his valued assistance.

Industrial Wastes

ACTIVATED SLUDGE TREATMENT OF KRAFT AND NEUTRAL SULFITE MILL WASTES *

By Ben V. Pearman, Jr. and Oliver B. Burns, Jr.

Pollution Abatement Department, West Virginia Pulp and Paper Company, Covington, Va.

The Covington, Va., mill of the West Virginia Pulp and Paper Company is an integrated pulp and paper mill producing sulfate and neutral sulfite semi-chemical pulp for paper and paperboard. Paper production is from six Fourdrinier machines, two on semi-chemical, the rest on bleached paper and light board while three cylinder machines produce heavy board.

About one-third of the total production is unbleached hardwood semi-chemical pulp, the remainder being bleached sulfate hardwood and kraft. Allied with the processes is a recovery system for the semi-chemical and sulfate spent cooking liquor and an activated carbon operation.

The mill is located on the Jackson River, a highly fluctuating mountain stream, which is the headwaters of the James River eventually terminating in the Atlantic Ocean. The Jackson River on occasion reaches a low flow of 40 m.g.d. This approaches the total mill fresh-water usage.

Due to the low flow and the constantly increasing mill production a means had to be found to curtail pollution of the stream. The result was the development and installation of a modified activated sludge waste treatment plant.

Historical Background

Before the installation of a large-scale waste treatment operation much had been done to control and eliminate pollution at its source. The production of activated carbon was sparked by just such thinking as this. It was found that the activation of raw leacher carbon from the rotary furnaces would produce a salable by-product and at the same time eliminate the practice of dumping the leacher carbon into the river. Following World War II, a large expansion and modernization took place at Covington and the pollution load became a more and more pressing problem to control. By 1950 the departmental reduction campaign had lessened the load greatly in proportion to production; however, the pollution was fast approaching an irreducible minimum.

The mountainous terrain at Covington precluded the possibility of lagooning the wastes and diminished the attractiveness of trickling filters as a means of pollution abatement. As a result, the activated sludge was the logical process to investigate.

It was an auspicious coincidence that the National Council for Stream Improvement had completed some promising laboratory studies at about this time to determine the feasibility of the activated sludge process as applied to pulp and paper mill wastes. It was found that with the addition of nitrogen and phosphorous as nutrients a synthetic sludge could be obtained and the process could be successfully adapted to kraft mill wastes. With this background theory a pilot plant was set up at Covington in the summer

* Presented at the 12th Purdue Industrial Wastes Conf.; Purdue University; Lafayette, Ind.; May 13–15, 1957.

of 1951 to evaluate various phases of the new treatment process. After about two years of pilot-plant operation, enough favorable data were available to recommend the construction of a full-scale plant. The company retained the services of consulting engineers for the sanitary design work. The combination of ideas, plus the industrial experience of the company, yielded for finished product a $2,000,000 nutrient-fed activated sludge waste disposal plant which was put into operation in May, 1955.

Plant Layout

Plant Design

The plant design is basically that for conventional activated sludge, but with some interesting modifications. Its maximum capacity is 24 m.g.d., with a design capacity of 16 m.g.d., about two-thirds of the total waste flow from the mill. This flow includes all wastes from the woodyard to about midway through the bleaching process, plus excess backwater from the semi-chemical paper machines and high alkalinity fly ash from two bark burning boilers. The remaining wastes from the mill are high-volume, low-B.O.D. effluents for which treatment would be superfluous.

The arrangement of the plant (Figure 1) commences with a primary settling tank 100 ft. in diameter, having a side-water depth of 12 ft. and with a theoretical retention time of 2 hr. This clarifier treats about two-thirds of the total flow while the remaining third, because of low suspended solids concentration, is by-passed to a mixing chamber. The mixing chamber collects the total influent after solids removal and affords a baffled mixture of influent with activated sludge and nutrients. From here an equal split of flow is effected to two combination aeration and settling units operating in parallel. These units provide a circular secondary clarifier surrounded by an annular shaped aeration chamber (Figure 2). The clarifiers are 175 ft. in diameter. The aeration channels around the units are 25.5 ft. in width and 15 ft. deep, providing a theoretical 3-hr. retention. The inner settlers or sec-

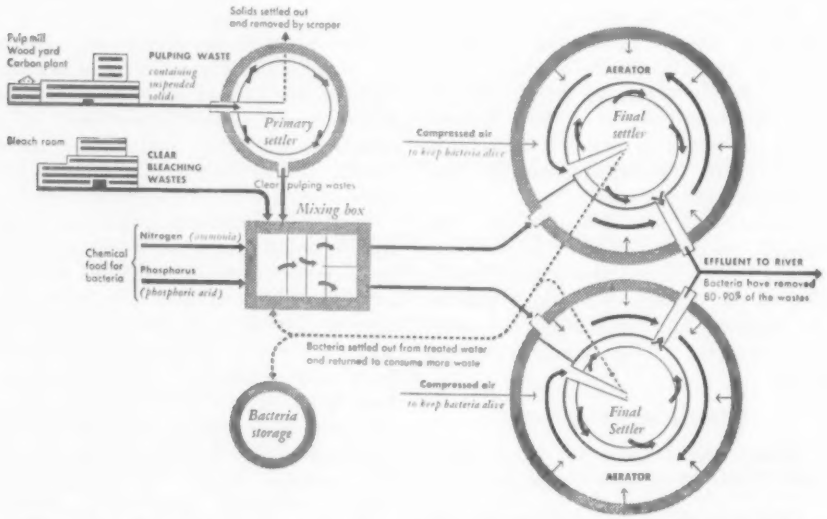


FIGURE 1.—Flow diagram of the waste treatment plant, West Virginia Pulp and Paper Company, Covington, Va.

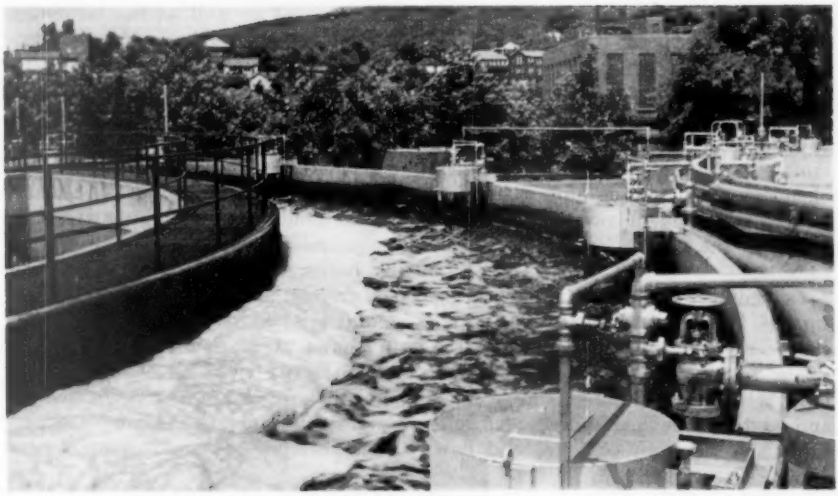


FIGURE 2.—Annular shaped aeration chamber circling the secondary clarifier (left, beyond railing).

ondary clarifiers have a 2½-hr. detention period.

The aeration chamber utilizes banks of impingement aeration equipment along the bottom outside walls and is sectioned into four compartments to prevent short-circuiting of the flow. A by-pass channel separates the aerator and the final clarifier and is used whenever repairs are necessary in the aeration chamber. Gates are installed between the channel and the aeration chamber so that any one compartment may be shut down without affecting the operation of the rest of the system.

The secondary or final clarifier is of conventional design except for the location of the effluent launder ring. This has been moved in about 10 ft. toward the center of the clarifier in place of the customary location at the circumference. With weirs on both sides of the trough, considerably lower over-flow rates are obtained as a result of the increase in total weir length.

The effluent from the final clarifiers goes directly to the river and the settled activated sludge is pumped back to the mixing chamber. Facilities are available for the storage or waste of this sludge as operating conditions warrant. The sludge storage tank is 50 ft. in diameter and 20 ft. deep. Mechanical aeration equipment is provided in this tank for agitation and aeration of stored activated sludge to preserve its quality. All wasted sludge, either primary or activated, is pumped to a lagoon and retained until a period when the river flow is sufficient to permit discharge without harmful results.

The nitrogen and phosphorus nutrients are in the form of 30 per cent aqueous ammonia and 75 per cent phosphoric acid solution. These chemicals are purchased in tank car lots and fed by conventional chemical proportioning pumps.

All the air blowers and various sludge pumps are concentrated in one building which also houses a laboratory equipped for plant testing and the master instrument control panel.

Instrumentation

Instrumentation for the plant is quite complete. Virtually every major operation is governed from one central control panel. On a console board all return and waste sludge pumps are

grouped with start-stop buttons and also variable speed drives. Controls for the four rotary positive displacement air blowers are also on this console and are equipped with indicators to show motor loads. The drive controls for the clarifier sludge rakes, chemical proportioning pumps, influent mixer, and influent raw waste pumps make up the remainder of the control console.

Immediately above the operating console is the panel board which records various data throughout the waste treatment plant. All influent flow, returned and excess sludge flow, and waste sludge flow are recorded continuously. The air pressure and flow are recorded as well as the torque on all clarifier rake drives. Also on this panel are pH, conductivity, and temperature recorders which register the respective values at various points throughout the plant.

In conjunction with the motor controls and various recorders is an alarm system mounted above the panel board. By means of flashing lights and warning horns, this system warns of various process upsets ranging from high conductivity to motor failure. The setup shows at a glance any pertinent change in the performance of the plant and thus provides means for immediate correction of operational trouble.

The compactness and completeness

TABLE I.—Operating Data, Waste Treatment Plant

Analysis	Period	
	January, 1957	Fiscal, 1956
Primary influent:		
Flow (m.g.d.)	8.70*	8.59
Susp. solids (p.p.m.)	1,062.0	611.0
B.O.D. (p.p.m.)	216.4	192.0
C.O.D. (p.p.m.)	956.0	774.0
Color (p.p.m.)	1,138.0	1,038.0
Bleaching wastes:		
Flow (m.g.d.)	5.66	4.22
Susp. solids (p.p.m.)	108.0	52.0
B.O.D. (p.p.m.)	164.1	187.5
Primary effluent:		
Flow (m.g.d.)	8.48	8.37
Susp. solids (p.p.m.)	152.0	129.0
B.O.D. (p.p.m.)	187.2	164.8†
C.O.D. (p.p.m.)	577.0	539.0
Color (p.p.m.)	1,131.0	1,079.0
Mixed wastes:		
Flow (m.g.d.)	14.14	12.59
Susp. solids (p.p.m.)	134.0	103.0
C.O.D. (p.p.m.)	683.0	681.0
Color (p.p.m.)	1,841.0	2,030.0
Aerator discharge:		
Susp. solids (p.p.m.)	2,506.0	4,025.0
Sludge vol. index (ml./g.)	236.0	106.0
C.O.D. (p.p.m.)	3,401.0	5,280.0
Returned sludge:		
Flow (m.g.d.)	4.26	4.16
Returned (%)	29.7	32.9
Susp. solids (p.p.m.)	8,987.0	13,410.0
Total solids (p.p.m.)	9,996.0	14,540.0
Volatile susp. solids (%)	89.0	86.0

* Includes semi-chemical backwater and fly ash flow of 1.19 m.g.d.
† October average only.

TABLE I.—*Continued*

Analysis	Period	
	January, 1957	Fiscal, 1956
Sludge storage:		
Sludge wasted (1,000 g.p.d.)	103.2	68.4
Susp. solids (p.p.m.)	6,760.0	—
Days sludge wasted (No.)	30.0	20.0
Waste total sludge:		
Flow (m.g.d.)	0.22	0.22
Susp. solids (p.p.m.)	10,357.0	7,075.0
Total solids (p.p.m.)	11,575.0	8,458.0
Volatile susp. solids (%)	56.0	55.0
Nutrients:		
Nitrogen (lb./day)	470.0	384.0
Phosphorus (lb./day)	106.0	101.0
Air:		
To aerators (1,000 cu. ft./day)	21,740.0	28,990.0
To storage tank (1,000 cu. ft./day)	906.0	—
Total air to waste volume ratio	1.51	1.48
Final effluent:		
Susp. solids (p.p.m.)	73.0	103.0
B.O.D. (p.p.m.)	47.2	63.5
C.O.D. (p.p.m.)	473.0	498.0
Color (p.p.m.)	1,995.0	2,178.0
D.O. (p.p.m.)		
Primary clarifier efficiency (%):		
Susp. solids reduction	86.0	79.4
B.O.D. reduction	15.7	12.9
C.O.D. reduction	41.2	32.0
Color reduction	3.1	1.2
Over-all efficiency (%):		
Susp. solids reduction	89.5	75.7
B.O.D. reduction	76.3	67.6
C.O.D. reduction	31.8	27.4
Color reduction	0.0	1.0

of this instrumentation arrangement makes possible the use of only one operator per shift to run the plant.

Operating Data

The operating data (Table I) are average values which might be expected at the plant in January, 1957. Conditions change quite rapidly so all values must necessarily be dated.

The primary influent flow is around 9 m.g.d. and the bleaching wastes average 5 m.g.d. In the primary influent the following average data obtain: 210 p.p.m. B.O.D., 800 p.p.m. suspended solids, 900 p.p.m. C.O.D., and 1,200 p.p.m. color. After primary settling this flow shows average values of about 190 p.p.m. B.O.D., 130 p.p.m. suspended solids, 700 p.p.m. C.O.D., and no noticeable color reduction. The unsettled bleaching wastes flow has 170 p.p.m. B.O.D. and 75 p.p.m. suspended solids. These two flows are joined and mixed to form the total plant influent to the secondary system.

In the mixing box, activated sludge and nutrients are added to the influent and this flow, now about 18 m.g.d., is divided equally to the two secondary units. The addition of activated sludge brings the suspended solids concentration up to about 2,500 p.p.m. in the aeration tanks. In each aeration unit the flow receives air at about 7,000 standard cubic feet per minute for 3 hr., after which it is discharged to the final settler for 2 hr. of settling. The

active sludge is removed from the bottom of this tank at a return rate of 4 m.g.d., 30 per cent of the influent flow, and returned to the mixing box.

The sludge volume index (Mohlman) in the aerators varies widely. It is between 70 and 250, although the returned sludge concentration remains fairly constant (9,000 to 10,000 p.p.m.) during these variations. The overflows from each final clarifier join at a common manhole and are distributed to the river through small ports in a submerged outlet pipe extending across the width of the river. This effluent averages 40 p.p.m. B.O.D., 450 p.p.m. C.O.D., and 80 p.p.m. suspended solids.

Nutrient additions are at the rate of 100 lb. of phosphorus and 400 lb. of nitrogen per day. Activated sludge is wasted through the sludge storage tank and the primary clarifier at about 100,000 g.p.d. (10,000 p.p.m., 85 per cent volatile) by controlling a sludge blanket depth at 3 ft. in the final clarifier.

The pH of the primary influent is 9 to 10, of the bleaching wastes 3.5 to 4.5 and throughout the secondary system about 7. Temperatures range from 80° to 100° F. depending on the season.

Operating Problems

Problems Overcome

Of much more interest than pure operating data are the problems encountered in operating the plant. One of the most notable of these, and a constant source of process trouble, is the control of influent pH. It has been found that the plant will operate well within a pH range of 6 to 8. Outside of this range sludge production decreases, as does B.O.D. removal efficiency. But more important than the instantaneous pH is the rate of change of pH. A fast change, say from 7 to 9 in the aerators, would do much damage, whereas, if this change were accomplished over a few days, rather than a few hours, the effects would be hardly noticeable. However, most of these rapid changes can be controlled if they can be foreseen before actually entering the plant.

In the Covington plant there is no provision for pH control as such, but by manipulation of various process wastes a certain degree of neutralization can be obtained. For example, suppose a very low pH discharge were inadvertently routed to the sewer from the carbon plant and the waste treatment plant was notified. The operator at the treatment plant would request the Recovery Department to backwash one of its cooking liquor filters to the sewer. This would deposit some very high pH caustic soda in the sewer and possibly neutralize the existing acid condition. The only protection available is activated sludge in storage. Approximately 150,000 gal. of active sludge is kept in storage at all times, and when a pH upset is imminent all the stored sludge is pumped into the aeration bays. This helps to buffer the effects of the pH change and preserve a reasonably efficient operation until the situation has improved.

Another damaging condition which existed at the time the plant commenced treatment was an excess of free chlorine entering the secondary system in the bleaching wastes. The chlorine sterilized the active bacteria immediately on contact with the activated sludge. Fortunately, it was found that the pulping wastes had a chlorine demand which would absorb all the residual chlorine from the bleaching wastes if given proper mixing and a short retention time. Therefore, a flash mixer was installed which completely integrated the two flows and eliminated free chlorine in the combined influent.

Before the elimination of the chlorine no excess sludge had built-up in the system, but about a month after this change the final clarifiers were virtually overflowing with activated

sludge. This presented a new problem in the control of the sludge level in the final clarifiers. To solve this a device was made up of glass tubing with a steel support that could be lowered into the final clarifier and used to bring up a cross section of the sludge blanket. By knowing the depth of the blanket, an accurate control was available to regulate the rate of wasting excess sludge. The sludge blanket measurement has now become a routine and important measurement in the control of the activated sludge process.

The control of suspended solids has been a big problem since the treatment plant was put in operation. Much difficulty was experienced in the primary clarifier with floating solids which passed under the launder ring and over the weir to the secondary system. To eliminate this, a ¼-in. stainless steel screen was installed around the periphery of the clarifier and a brush mounted on the scum skimmer arm to continually clean the screen. This arrangement has worked well in keeping floating solids from leaving the primary clarifier. However, high suspended solids have still remained in the combined effluent to the river. Some decrease in solids has been achieved by reducing the concentration of suspended solids in the aerators.

Inherent Problems Remaining

By the same token that there are problems which have been solved there are also problems which remain to be solved. Not the least of these is the application of standard analytical tests to the plant wastes. For example, the Winkler test cannot be used to measure dissolved oxygen due to inherent interference in the waste; therefore, a polarograph must be used for this test. Other tests, such as phosphorus and nitrogen, show similar interferences. The B.O.D. test is erratic on certain waste flows and is run in duplicate on certain wastes. These interferences create a problem in that many extra and complex operations must be performed to produce a test with sufficient accuracy. Also the tests become too cumbersome or complicated to be run as daily routine and thus require laboratory work outside of the duties of the regular operator.

One of the biggest factors in test interferences is the natural color of the wastes. The wastes which enter the primary clarifier are a very dark grey in color while the bleaching wastes exhibit a very intense reddish brown. The color combination of the two flows is a dark grey-black which undergoes little or no reduction during passage through the plant. The color cannot be filtered out and is so intense that it cannot be measured properly.

Along with the constant high color in the wastes is a high frothing potential. The aerators must be treated with antifroth agents almost continuously to avoid frothing out of the bays. Also this same type froth is present almost constantly in the river and is especially pronounced during low river flows. Very little can be done to eliminate this condition and the antifroth agents used for its control present quite a high cost factor.

The primary influent wastes also have a great tendency to deposit carbonate and sulfate scale on any surface. This is especially troublesome in the scaling of pH and conductivity electrodes. In one day enough scale can build up to make the pH electrodes in the waste inoperative. The sludge rakes, the weir, the effluent screen, and virtually all equipment touching this waste is scaled badly. As much as 3 in. of scale has been noted on the sludge rakes. This condition is one which will require some basic research to eliminate.

Design Considerations

Along with the adverse effects of the waste itself some difficulties have been

presented from inadequate initial plant design. The foremost problem in this area is the constant clogging of the aeration equipment. The equipment is of the impingement type and employs a jet of liquor impinging on a jet of air to shear the air into tiny bubbles. However, due to the nature of the waste, these liquor nozzles and air orifices become plugged and must be dismantled and cleaned to maintain efficient aeration. To clean the equipment an aeration bay (one-eighth of the aeration capacity) must be drained directly to the river and kept out of service for at least 24 hr. while the equipment is being cleaned. The entire aeration system is cleaned 2 to 3 times per year; however, this is much less than is really necessary to maintain proper aeration efficiency. Another drawback to the equipment is the fact that due to the large (¼-in.) air orifices a power failure that stops the flow of air for as little as 1 min. allows liquor to enter the air header. When the air is turned back on, the liquor dries in the header and quickly clogs it. It is not uncommon to find a 1-in. layer of dried sludge on the inside of the air header after a power failure of this sort.

Another troublesome design factor incorporated in the treatment plant is the use of a wet air scrubber. The scrubber entrains moisture in the air entering the blowers creating a scale and rust problem. A dry air filter would seem the more proper equipment.

One other factor exists, which is not altogether desirable, but does not affect the plant efficiency as such. This is the placement of the air blowers. The blowers are in the same building, although separated by a wall, as the laboratory and control panel. These blowers set up heavy vibrations in the laboratory and create a high noise level which is quite annoying to persons in and around the building. Although mufflers were considered in the initial design they were not adopted. In any future design it would seem advisable to separate the blowers from the control room sufficiently to reduce the noise and vibration to a minimum.

The design of the plant in most respects, excepting the points just mentioned, is good. Some unique features have been incorporated which are of great benefit. Among these is the consideration given to the control of froth. The aeration bays are designed with a 3-ft. freeboard to contain moderate froth build-up. The final effluent manhole employs an automatic butterfly valve which controls the level in the manhole so that the outflow is always from under the liquid level thus keeping froth out of the outfall pipe. Also the effluent is distributed across the entire width of the river and introduced below the river surface level which lessens the chance for formation of froth. Less froth is experienced at the final effluent weir since the overflow rate has been reduced by utilizing the double walled weir.

Other design points which are very commendable include the nutrient addition layout, the influent control chamber, the flexible piping arrangement, and the general high degree of instrumentation. The plant is exceedingly compact and versatile in arrangement so that many combinations of experimental ideas may be tried without having to change the existing facilities.

Achievements of the Process

The actual tangible benefits which occur from the operation are best described by average efficiency data. On a B.O.D. basis, the plant treats 70 per cent of the mill wastes, and removes 75 to 80 per cent of the B.O.D. in the wastes treated. This amounts to reducing the total mill pollution to the river by more than 50 per cent. In suspended solids removal, the plant has

TABLE II.—Comparative Pollution Abatement Costs

Item	Average Monthly Treatment Costs ($)		
	1954*	1956†	Change‡
Operating labor	210.00	1,800.00	1,590.00
Employee benefits	180.00	850.00	670.00
Repair labor	700.00	2,300.00	1,600.00
Repair material	560.00	1,500.00	940.00
Operating supplies	70.00	2,900.00¶	2,830.00
Electricity	1,045.00	2,300.00	1,255.00
Cartage & cranes	35.00	30.00	−5.00
General expense	840.00	520.00	−320.00
Salaries	2,800.00	2,800.00	0.00
Depreciation	1,110.00	13,000.00	11,890.00
Other expense	805.00	290.00	−515.00
Total	8,355.00	28,290.00	19,935.00

* Before operation of waste treatment plant.
† After operation of waste treatment plant.
‡ Increase or decrease (−) in costs due to installation and operation of waste treatment plant.
¶ Chemical costs:

Nutrient ammonia	$ 800 per month
Nutrient phosphoric acid	$ 560 per month
Total nutrient cost	$1,360 per month
Defrothant cost	$ 0.00 to $2,300 per month

an efficiency of 85 to 90 per cent. This reduces the total mill suspended solids to the river by better than 75 per cent. The plant has a total solids removal efficiency of about 30 per cent and a C.O.D. removal efficiency of 35 per cent.

The summation of these benefits is shown by the results of an annual biological survey of the Jackson River by the Institute of Paper Chemistry. The survey last summer, based on the quantity of sensitive bottom organisms, showed that the treatment plant has directly effected a recovery of 15 miles of stream after only one year of operation.

Costs

The costs of operating the pollution abatement program are tabulated on a basis of "before and after" installation of waste treatment. Table II gives average monthly costs for the fiscal years 1954 and 1956. The treatment plant was put into operation in May, 1955.

The $8,045.00 per month operating cost will probably be reduced in the future as new and better methods of operation are developed. Reductions can be effected in repair, labor, and materials and possibly in operating supplies. The first year of operation presented unforeseen difficulties which are now being overcome and thus should reduce the costs proportionally. The costs incurred before the treatment plant was constructed were attributable to daily stream survey and mill sewer work which is still being done.

Future Plans

There is much work to be done on the future waste treatment program at Covington. Practical in-plant activated sludge variables are being studied in an effort to improve the B.O.D. removal efficiency of the process. The investigations already underway or planned for an immediate start include: (a) analysis of sludge respiration rates and influencing factors, (b) possibility of reaerating activated sludge, (c) factors controlling the SVI, (d) optimum aerator suspended solids concentration, and (e) effects of anti-froth agents on respiration rates and oxygen transfer efficiency.

In the constant fight against froth, an experimental spray system is being installed on two of the aeration bays to test the effectiveness of spraying final effluent as a froth-breaker. The system will be designed for use with plant effluent, raw water, filtered water, and anti-froth agents, or any combination of these. It is hoped that something can be developed to decrease or preferably eliminate the use of anti-froth agents.

The last, and most basic, field of research for improvement of the process is being carried out in the development of means to remove the color from the effluent. A research fellowship has been granted Virginia Polytechnic Institute by the company to perform basic research on this problem. The character of the influent wastes is such that an estimated 60 per cent of the

total color is contributed from the caustic extraction stage of bleaching. Therefore, since this particular waste makes up less than 10 per cent of the total volume of the plant influent, all effort is being concentrated on developing a method of removing this color. This is undoubtedly a long range problem but certainly not an impossible one.

Conclusion

After operation of a year and although some problems still remain, full confidence can be placed in the ability of the supplemented activated sludge process to successfully treat the kraft and neutral sulfite mill wastes at the Covington, Va., mill of the West Virginia Pulp and Paper Company.

MEETINGS OF INTEREST

1957

Oct. 14–18	**American Society of Civil Engineers,** Annual Convention, Hotel Statler, New York, N. Y. W. H. Wisely, Executive Secretary, 33 West 39th St., New York 18, N. Y.
Oct. 19	**Conference of Wisconsin Sewage Works Operators,** Two Rivers, Wis. C. A. Kelley, Secretary-Treasurer, Elkhorn, Wis.
Oct. 21–23	**Engineers' Society of Western Pennsylvania,** Annual Water Conference, Penn Sheraton Hotel, Pittsburgh, Pa.
Oct. 21–25	**National Safety Congress and Exposition,** Conrad Hilton Hotel, Chicago, Ill.
Oct. 28–30	**American Nuclear Society,** Winter Meeting, Henry Hudson Hotel, New York, N. Y.
Oct. 29	**Conference of Federal Sanitary Engineers,** Hotel Statler, Washington, D. C. (3 to 5 PM)
Oct. 30–31	**Industrial Hygiene Foundation,** Annual Meeting, Mellon Institute, Pittsburgh, Pa.
Nov. 11–15	**American Public Health Association,** 85th Annual Meeting, Cleveland, Ohio. R. M. Atwater, M.D., Executive Secretary, 1790 Broadway, New York 19, N. Y.
Nov. 19	**Water and Air Pollution Conference,** University of Missouri, Columbia, Mo.
Dec. 1–6	**American Society of Mechanical Engineers,** Annual Meeting, Hotel Statler, New York, N. Y. Secretary, ASME, 29 West 39th St., New York 18, N. Y.
Dec. 8–11	**American Institute of Chemical Engineers,** Annual Meeting, Conrad Hilton Hotel, Chicago, Ill. F. J. Van Antwerpen, Secretary, 25 West 45th St., New York, N. Y.

A BROAD PICTURE OF INDUSTRIAL WASTE POLLUTION ABATEMENT*

By Blucher A. Poole and Perry E. Miller

Respectively, Director, Bureau of Environmental Sanitation, Indiana State Board of Health, and Technical Secretary, Indiana Stream Pollution Control Board;
and
Chief, Industrial Waste Section, Division of Sanitary Engineering, Indiana State Board of Health

Whether you represent industry, a municipality, a regulatory agency, or are a sportsman, you have a responsibility for protecting the greatest of all resources—water. No one has a greater stake than industry in the management of water resources.

Notwithstanding industry's great demands for water, many other important water uses must be recognized and protected. Included are domestic uses, agricultural uses (including irrigation), fishing, water sports, navigation, and power developments. It is inevitable that conflicts will arise between these various interests. And these conflicts will increase as industries and populations grow. As they increase, government will intervene to a greater degree in an attempt to lessen controversy and to provide maximum benefits from the use of the water resources. Pollution abatement will take on greater importance than it does today.

It has been said the Ohio River Valley Water Sanitation Compact is a unique experiment in government. The framers of ORSANCO showed great foresight in uniting the efforts of eight states to control water pollution in the Ohio Valley. The abundance of water has had much to do with the growth of the Ohio Valley. How well this water is managed in the future will determine how long the phenomenal industrial development will continue.

* Presented at the 1957 Annual Meeting, Ohio Sewage and Industrial Waste Treatment Conf.; Dayton, Ohio; June 19–21, 1957.

Ohio Valley Industrial Wastes

Since practically every type of industry is present in the Ohio Valley, the industrial waste problems are many and varied. Industrial wastes are classified many ways. They may be divided as follows:

1. Oxygen-consuming wastes high in suspended or dissolved solids.
2. Taste and odor-producing wastes.
3. Oily, greasy and/or colored wastes.
4. High temperature wastes.
5. Toxic or acid wastes.
6. Wastes containing inert solids.

Methods of treatment vary greatly. Many of the oxygen-consuming wastes and those containing settleable solids can be handled by conventional treatment works. Wastes from milk processing, distilleries, and packinghouses can be treated successfully and it is merely a matter of the sanitary engineer designing adequate facilities. Pulp mill wastes on the other hand are not so amenable to conventional treatment and the cost of high-grade treatment may become prohibitive. Therefore, pulp mills must locate where there is sufficient dilution water at all times to assimilate the partially treated wastes or new methods of treatment must be developed.

Other types of wastes such as metal-finishing wastes can be reduced or removed by chemical treatment; however, the treatment works require close supervision if they are to produce a continuously satisfactory effluent. Solid

wastes like flue dust and mill scale from steel mills can be recovered and are of considerable economic value to the companies. However, many of the older mills are faced with the practical problem of having no place to locate the treatment works.

Toxic Wastes

Toxicity is the most challenging industrial waste problem. Too often toxic wastes are associated only with spectacular fish kills or the death of farm animals. Regulatory agencies have been concerned mainly with maintaining the levels of toxic compounds below a death-producing concentration for man, animals, fish and aquatic organisms. Very little is known of the long-range effects of trace elements on man or higher animals. There is much to be learned also about the synergistic effects of mixing two or more elements or chemical compounds in a stream.

The chemical industry has become so complex, and it is changing so rapidly, no administrative agency can expect to keep up with it. The situation as it exists today, where a regulatory agency must accept largely on faith the statements of industry representatives on the effects of a group of compounds, is unsatisfactory. Some regulatory agency people who have worked with industrial waste for a considerable period of time wonder if industry representatives know any more about the effects of some of their wastes than they do. If industry representatives do, they are not always making the information available to the regulatory agencies. Whether industry likes it or not, the time will come when it will be required to furnish positive proof its wastes will have no deleterious effect before it is permitted to put them into a stream. The food and drug manufacturers follow this rule before marketing their products.

Radioactive Wastes

Wastes from nuclear power reactors contain some of the most toxic materials ever handled by man. No treatment is known for reducing the radioactivity of an element or compound. Concentration and storage or dilution become the only acceptable means of waste disposal. The fact that the time required to accomplish a satisfactory reduction in radioactivity by decay is much greater than the life of the storage materials being used is cause for concern, as are the methods of controlling the discharge of the low level or intermediate level wastes. The power reactor at Shippingport, Pa., is bringing these problems to the forefront throughout the entire Ohio Valley.

Housekeeping

Process changes and housekeeping are areas of industrial waste disposal where greater advances can be expected. Good housekeeping is a prime requisite for the maintenance of good operation and the prevention of pollution. Waste products should be removed at their source whenever practicable. In cases where wastes can be eliminated or reduced by process changes, these should be considered in lieu of waste treatment works.

Industrial Pollution Abatement

Many outstanding examples of pollution abatement can be cited throughout the Ohio Valley. Two examples from Indiana are those of cyanide control and acid mine drainage.

Cyanide

Several instances of fish and animal kills occurred downstream from metal plating plants. These kills were traced to mechanical failures of equipment and human errors that resulted in concentrated cyanide solutions being discharged to the stream. Following a serious accident that created a potential threat to a large public water supply, the Indiana Stream Pollution Control Board adopted a cyanide regulation. This regulation requires all cy-

anide and cyanogen compounds in use and in storage to be contained to prevent them from escaping directly or indirectly into any sewer system or watercourse. Usually a simple curbing around the plating tank with no connection to a floor drain is all that is required. The curbed area must provide a volume equal to or greater than the tank being protected. Voluntary compliance with this regulation has virtually eliminated toxic concentrations of cyanide in Indiana streams.

Acid Mine Drainage

In the case of acid mine drainage, work was begun with the manager of the Indiana Coal Association. Through this effort the strip mine owners have sealed many of the old workings and are now sealing the new workings before moving out of an area. Flooding of the acid-forming materials in strip pits has produced many good fishing spots in the southern part of Indiana.

An interesting sidelight is that the use of gob (mine waste) for roads was found to be a major contributor of acid drainage following periods of rainfall. To reduce this pollution, several companies have discontinued the use of gob for roads. In addition to reducing pollution, this has reduced maintenance of trucks and prolonged their useful life.

Although improvements have been made, the mine drainage problem in Indiana has not been eliminated. The situation has been improved and further improvement can be expected. It will not be completely resolved until someone develops a satisfactory means of handling drainage from shaft mines. The mine drainage picture for the Ohio Basin as a whole is not as good as the Indiana situation would lead one to believe. It is understood the sealing of strip pits does not work satisfactorily in the eastern part of the basin. The eastern part of the basin also has a greater percentage of slope and shaft mines than has Indiana. Acid mine drainage is still one of the most significant unsolved industrial waste problems of the Ohio Basin. The coal industry is cooperating with research and it is hoped results will be forthcoming soon.

ORSANCO

ORSANCO was formed to bring together the powers of each of the eight Ohio Basin states to control future pollution and abate existing pollution. The compact spells out the minimum requirements for the treatment of sanitary wastes. On industrial waste, the following statement is made: "All industrial wastes discharged or permitted to flow into the aforesaid waters shall be modified or treated, within a time reasonable for construction of the necessary works, in order to protect the public health or to preserve the waters for other legitimate purposes, including those specified in Article I, to such degree as may be determined to be necessary by the Commission after investigation, due notice and hearing." Article I states in part ". . . to maintain the waters of said basin in a satisfactory sanitary condition available for safe satisfactory use as public and industrial water supplies after reasonable treatment, suitable for recreational usage, capable of maintaining fish and other aquatic life, free from unsightly or malodorous nuisances due to floating solids or sludge deposits and adaptable to such other uses as may be legitimate."

The compact became a reality on June 30, 1948. In keeping with one of the basic philosophies of the Commission, that of attaining its goals through the medium of education and persuasion where possible, industrial action committees were formed to study their waste problems and to provide information for the Commission on the pollution abatement needs of the particular industry, on methods of treatment, and on the development of waste analysis and control methods.

Some of the committees have published, through the Commission, reports on treatment methods, waste reduction methods, research, and other pertinent factual data. What is perhaps more important, these committees have developed a "waste consciousness" in the industries they represent which never existed before. This has been translated into concrete improvements at many locations and a resultant lowering of the industrial waste load of the Ohio Basin. Worthy of particular mention are the achievements of the Metal Finishing and the Steel Industry Action Committees. These committees have demonstrated conclusively that industry and regulatory agencies can sit down and work with each other to the ultimate benefit of all water users.

On April 6, 1955, the Commission adopted "Industrial Waste Control Policy and Procedure" for expediting the Commission's control program on interstate waters and to furnish existing and new industry on these waters information with regard to control of waste discharges. The basic industrial waste requirements are as follows:

Industrial wastes (exclusive of mine drainage until such time as practical means are available for control) shall be treated or otherwise modified prior to discharge so as to maintain the following conditions in the receiving waters:

1. Freedom from anything that will settle to form putrescent or otherwise objectionable sludge deposits which interfere with reasonable water uses.
2. Freedom from floating debris, scum and other floating materials in amounts sufficient to be unsightly or deleterious.
3. Freedom from materials producing color or odor in such degree as to create a nuisance.

These conditions to be maintained in the receiving waters following the discharge of industrial waste effluents, are basic or minimum requirements. Investigations will be conducted by the Commission as time and circumstances permit to establish the need and validity of altering or adding to the above basic requirements.

Questions concerning compliance with requirements are to be addressed to the signatory state agency in the state in which the industrial plant is operating. Arrangements will be made by the state agency for such contact and consultation with the Commission as may be necessary or requested.

The policy statement also says that

TABLE I.—Comparison of the Number of Industrial Waste Facilities in the Ohio Valley, Ohio, and Indiana on July 1, 1952 and July 1, 1956

Status	1952			1956		
	Ohio Valley	Ohio	Indiana	Ohio Valley	Ohio	Indiana
Adequate control facilities	282	18	95	654	200	146
Per cent of total adequate	22	7.8	42.1	45.5	47.6	67
Control provided not adequate	234	68	80	449	187	56
Control facilities inadequate, improvements under construction	46	7	22	34	30	1
New control facilities under construction	42	—	5	34	2	3
Plans for facilities completed or in preparation	150	8	3	92	2	5
No action by industry	189	104	11	175	1	7
Total number of industries	1,270	230	226	1,438	422	218
Number of industries complying with ORSANCO IW-1	—	—	—	965	346	154

TABLE II.—Status of Industrial Waste-Control Facilities* by Ohio Basin States—July 1, 1956

Status	Ill.	Ind.	Ky.	N.Y.	Ohio	Pa.	Va.	W.Va.	Total	Per Cent of Total
Adequate control facilities	6	146	103	4	200	88	21	86	654	45.5
Control provided, not adequate	9	56	60	20	187	54	11	52	449	31.2
Control facilities inadequate, improvements under construction	0	1	3	0	30	0	0	0	34	2.4
New control facilities under construction	0	3	0	1	2	12	1	15	34	2.4
Plans for facilities completed or in preparation	0	5	0	10	2	58	0	17	92	6.3
No action by industry	0	7	0	17	1	23	10	117	175	12.2
Total number of industries	15	218	166	52	422	235	43	287	1,438	100.0
Number of industries complying with ORSANCO IW-1	15	154	125	4	346	213	31	77	965	67.1

* For industries discharging effluents directly into streams.

"tailored" requirements will be developed when needed, through and in cooperation with the appropriate state agencies. Further, for establishing waste control requirements the Commission will employ quality criteria, these criteria to be applied at point of use.

The Commission is conducting studies to reveal where more industrial waste control should be exercised beyond the basic requirements already promulgated. Studies on criteria for chlorides, hardness, and phenols are also nearing completion.

At the recommendation of the Steel Committee, ORSANCO adopted a resolution on January 24, 1957, which is intended to stop the indiscriminate discharge of abnormal amounts of phenolic substances from industrial plants into the Ohio River and its tributaries. This action was brought about as a result of repeated abnormal phenolic discharges usually occurring over weekends, presumably during periods of routine cleanup and adjustment of plant operations. The slug effect of these discharges creates a serious problem at municipal water supply plants. This resolution has been sent by the individual states to all industrial plants known to be discharging phenolic substances to the Ohio River and its tributaries.

Table I shows the number of industries and the status of treatment works in the Ohio Valley and the States of Ohio and Indiana for the years ending July 1, 1952 and July 1, 1956. These data are taken from the fourth and eighth annual reports of ORSANCO. In the four year period, 1952 to 1956, the number of industries discharging directly to the waters of the basin increased from 1,270 to 1,438; the number providing adequate treatment is now 654 compared to 282 in 1952. Similarly for Ohio the number of industrial waste discharges increased in

TABLE III.—Industrial Waste Report, American Maize Products Company

Date	Analysis—Lake Michigan Outlet										
	B.O.D. (p.p.m.)	Flow (m.g.d.)	Pop. Equiv.	Total Solids (p.p.m.)	Susp. Solids (p.p.m.)	Ash (p.p.m.)	Protein (p.p.m.)	Sugar (p.p.m.)	pH	Chlorine Residual (p.p.m.)	M.P.N. Coliform Bacteria per 100 cc.

TABLE IV.—Industrial Waste Report, Rockwell Spring and Axle Company

Date	Day	Flow (1,000 g.p.d.)	Industrial Waste Analysis (p.p.m.)						
			pH	Cr	Cr+6	Fe	Cu	Ni	Susp. Solids

four years from 230 to 422. In 1952, 18 provided adequate treatment compared with 200 in this category in 1956. The decrease in Indiana industries maintaining their own outlets (from 226 in 1952 to 218 in 1956) is due in part to a campaign to get industries connected to city sewers where practicable. While the rate of progress since 1952 has been less in Indiana than in Ohio it will be observed that the percentage of industries with adequate treatment is considerably higher in Indiana.

Table II shows the status of industrial waste control facilities on July 1, 1956 for the entire Ohio Valley. This table is taken from the eighth annual report of ORSANCO. Of the total industrial discharges, 45.5 per cent provide adequate treatment and 47.6 per cent of the Ohio industries have adequate facilities. It should be noted that 67.1 per cent of the industrial discharges in the basin comply with the basic industrial waste requirements as set forth by ORSANCO.

Use of Waste Analysis Reports

Pollution abatement can and should be used as a tool to improve and control production. Waste analysis reports are being used by the following two companies to control and improve production methods and not merely as monitoring reports of waste products.

The American Maize Products Company, Hammond, Ind., formerly used an empirical formula for calculating yields. After establishing a waste analysis program they found the formula in error. The calculated yields plus the wastes in the sewer exceed the raw products used—in other words, exceeded 100 per cent of the raw product. Top management now uses the waste analysis report to check the efficiency of the operations in each department. The waste analysis reports are discussed regularly at foremen meetings and have proved a valuable tool in improving production methods and operations. Table III shows the headings for the waste analysis reports of American Maize Products Company.

Another example is that of Rockwell Spring and Axle Company. For several years this company has been conscious of its responsibilities for pollution abatement but only in the last few months has it been using waste control analysis to compare losses and operations at several plants. There appears to be little doubt that this comparison will result in improved operations and a more effective water pollution abatement program at all of the Rockwell plants. Table IV shows the headings of the monthly operating reports of the Mishawaka Plant.

Conclusions

Even though great strides have been made in industrial wastes control, much remains to be done before industrial waste pollution is abated. The program requires the ever-increasing and unremitting effort of all. The broad picture of industrial waste pollution abatement is bright and the industrial development of the Ohio Valley is in the hands of industry, regulatory agencies, engineers, plant operators and every interested citizen. How well each one does his job and sells industrial waste control, will determine the industrial development of the Ohio Valley for this and future generations.

TWO-STAGE FILTER OPERATION AT THE UPJOHN WASTE TREATMENT PLANT*

By L. B. Tompkins

Waste Treatment Plant Superintendent, The Upjohn Co., Kalamazoo, Mich.

The Upjohn Company is a major producer of pharmaceuticals and one of the largest producers of antibiotics, cortisone, hydrocortisone, folic acid, adrenal cortex, and other steroids. All manufacturing is done at the Portage Road plant, which is about six miles south of Kalamazoo, Mich. The main manufacturing plant, covering some 33 acres, is what is called a "flexible" factory. This is to provide for complete flexibility of future operations, room to expand, room for new machines, and room to convert quickly from one product to another.

The waste treatment plant was started in the Spring of 1948 with only antibiotic wastes, as the other manufacturing buildings were still under construction at that time. The treatment plant effluent was to discharge into Portage Creek, which is a trout stream. The creek also flows through a park, which has a swimming pool. The creek has a total estimated flow of 36 m.g.d. The plant effluent was limited to 100 lb. of B.O.D. per day, with chlorination from May 15 to September 15 providing a 0.5-p.p.m. residual.

Early Operating Troubles

During most of the first year there were digester troubles. The digester was double the volume first intended. During preliminary tests of the wastes it was thought that there would not be much sludge, but the state health department recommended that the capacity be doubled because it frequently was needed in most plants. This was very good advice; as it turned out it has been necessary quite frequently to haul sludge that cannot be pumped into the digester. The capacity of the digester is 112,500 gal.

In the Fall of 1948 the filters started ponding, caused by a build-up of solids and grease on the filter stone. During this time attempts were being made to eliminate the grease and smooth out the flow of antibiotic spent beer coming into the plant. The actual B.O.D. load was not great. The difficulty came from the slugs of spent beer, which upset the plant all the way through. Eventually a pumping schedule was worked out so that the wastes were pumped in slowly over a longer period of time. Two 25,000-gal. aeration tanks were used to aerate the spent beer, one being pumped out while the other was filling. This worked quite well for a time.

Dilution Not a Help

The original tests had indicated that dilution of the wastes with waste storm sewer water would get the best results from the filters. But in actual operation the waste was pushed through the plant without enough recirculation, and consequently it was not fully treated. This was done while operating the filters in series.

To prove the value of dilution, the filters were then operated in series using dilution with storm water; then without storm water, but in series using recirculation water from the final tank; and finally with parallel operation using final make-up water for re-

* Presented at the 1957 Annual Meeting, Michigan Sewage and Industrial Wastes Assn.; Traverse City, Mich.; May 20–22, 1957.

circulation. It was decided that parallel operation without dilution water gave best over-all results with reduced ponding and better B.O.D. reduction.

1952 Expansion

This parallel flow to the first 90-ft. filters was used in the plant expansion in 1952, except that the filter effluent was pumped by the recycling pumps through the preliminary tanks and mixed with the raw incoming waste. This also ended the troubles arising from grit, and from sediment coming out of the filters and being pumped back directly onto the filters and bearings.

Increased production and a new antibiotic in the Spring of 1952 resulted in a recurrence of operating trouble. The new antibiotic beer waste had a B.O.D. of 20,000 to 30,000 p.p.m., whereas the other antibiotic wastes had B.O.D.'s of about 5,000 p.p.m. This, of course, caused a big overload on the plant and also resulted in many odor complaints.

It was decided in April, 1952 to expand the plant and to haul away all the spent beer that could not be taken through the plant. During this time the wastes had been chlorinated very heavily to avoid trouble. Everything was also being done to improve the plant efficiency, such as improving the settling tanks. At times the effluent of the settling tanks was almost as high in suspended solids as was the influent.

Settling efficiency was improved considerably by installing boards across the tops of the baffles and then installing a diagonal type of slat for 2 ft. below the existing baffles. A check had been made with fluorescent dye and by other methods before adding the baffles. At this time there was a tendency for the waste to flow across the surface of the tank and go out in about 10 min., although the detention time of the tanks was 2 hr. The waste was light and flocculated and probably the emulsified grease helped to carry the solids through in suspension. Also, there was a good chance that the different temperatures of the wastes coming in might tend to stratify the wastes.

The original plant had a maximum capacity of 700,000 g.p.d. with two 90-ft. filters containing 6 ft. of limestone from 2 to 3 in. in size. There were two primary sedimentation tanks with 2-hr. detention and two final sedimentation tanks with 2-hr. detention. The expansion program called for a primary tank of the same capacity as the two old ones. The old final tanks were used for the intermediate tanks, and a new 120-ft. filter containing a 6-ft. depth of limestone was installed. Two new final sedimentation tanks were also added. Figure 1 shows the flow diagram of the expanded waste treatment plant.

The pump capacities were doubled, to 550 g.p.m. per pump, and the two pumps were run at all times. This allowed use of two sewage pumps rated at 1,100 g.p.m. and two recirculating pumps rated at 1,100 g.p.m., totaling 2,200 g.p.m. pumping through the primary sedimentation tanks. Make-up water filter effluent to maintain constant flow for the sewage pumps comes back into the wet well from the filter effluent when needed. This flow is controlled by an automatic valve. The plant expansion was completed in the Spring of 1953. During this expansion program no flow was by-passed at any time.

Tank Hopper Changes

During this construction period a few items of plant equipment were changed. Among these are the plug valves on all sludge hoppers. The original plan for the new expansion called for pumping from all 10 sludge hoppers (four primary, two intermediate, and four final). This looked like a time-consuming operation. Therefore, a line was connected so that the sludge from the intermediate and final tanks could be drawn back to the wet

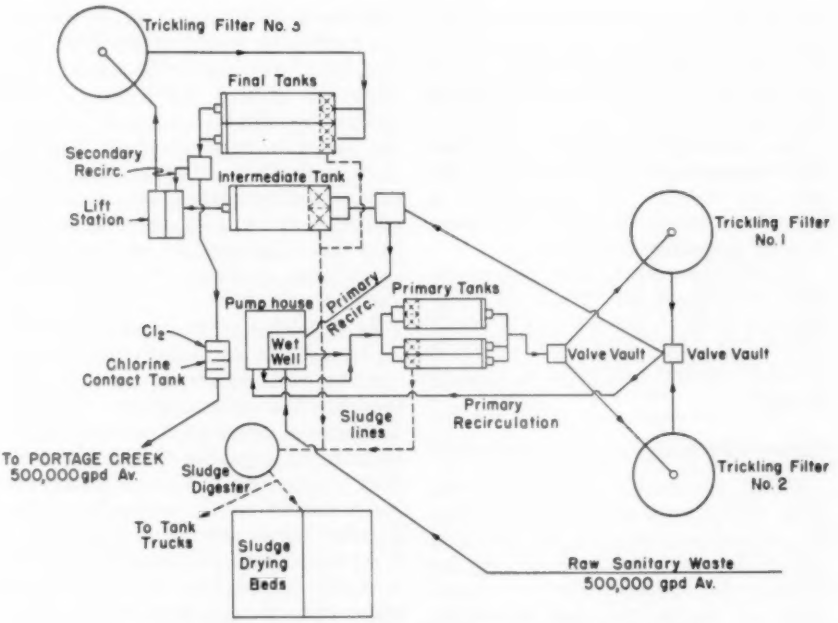


FIGURE 1.—Flow diagram of expanded waste treatment plant.

well during the night and concentrated in the primary tanks by 8 AM. In this way the amount of sludge to be pumped or hauled would be known.

The pipelines are connected so that sludge from these hoppers can be either pumped or withdrawn by gravity. This operation has worked very well and had saved a lot of time for the day men. The sludge quantity varies considerably at times. This could be caused by changes in production schedules, filters unloading, and maybe, at times, by some chemicals or solvents coming in that may cause some unseasoned unloading of the filters.

The B.O.D. and suspended solids determinations are made over the five-day week unless there is a necessity for checking on weekends. This is not often, because the waste flow is lower and as recycling is increased the plant clears up over weekends. A system of automatic samplers collects samples over the 24-hr. period. These samplers, operate on a solenoid take-off and can be set for different intervals and quantities, permitting automatic sampling in amounts and at the times desired.

Aeration Tank Improvements

Another important unit operation that has been worked on is the aeration tanks. High B.O.D. antibiotic plant wastes are pre-aerated before treatment. The piping was rearranged so the incoming wash water and spent antibiotic beer would have to follow a U-shape pattern. This has extended the detention time considerably. Formerly the waste passed from one tank to the other by either overflowing or by passing through a valve between the tanks. Three different types of aeration jets have been tried; the last to be tried and now in use is an air-liquid type. These jets cause a rolling motion in the tanks, which keeps solids from settling on the bottom of the tanks. This has helped.

At the same time a grit chamber was installed on the aeration tanks. Also,

recording meters were installed on the various pumps and the air supply. These give better control and it is now possible to tell when pump pressures fall, etc.

The antibiotic spent beer is fed into the aeration tanks continuously, 24 hr. per day, 7 days per week. This is thought to have helped keep the filters in good operating condition.

No pH adjustments have been necessary. The spent beer has a pH ranging from 2 to 11, but when it is mixed with large volumes of wash water, it is nearly neutral and remains so until treated.

Digester Problems and Improvements

During the trouble with the digesters many things were tried. In the original preliminary tests for the construction of the plant, the methods used for making the digester work on these types of wastes were not successful. There was some thought that it might be made to work after more sanitary waste could be mixed with the antibiotic wastes.

After about two months of operation the digester gave indications that it might start operating, but about this time the plant started getting more and more solids. The attempt to load them all into the digester may have delayed the start that had been hoped for.

In the Fall of 1948 so many solids had accumulated that they had to be hauled in tank trucks. There also were many odor complaints. Because the solids were being hauled away it was decided to rest the digester and add lime to raise the pH. As the pH increased to 7, the digester slowly started to produce gas; however, the gas would not burn and had a bad odor. Bottle gas was installed for a pilot line to make the gas burn. This worked until the digester finally produced burnable gas of its own with a carbon dioxide content of about 35 per cent.

As the work on the digester was in progress it was decided to set up several small digesters to see if each of the antibiotics would digest alone, and find out if any particular one of them might be causing the trouble. Seed sludge was obtained from a city sewage plant and temperature and pH were controlled. Most of the laboratory digesters worked, but some were rather slow. In fact, one was so slow that there was thought of dumping it —but then it began producing more gas than any of the others.

In December, 1955 digester gas production slowly decreased until the production was zero. At first it was thought that something toxic had hit the digester, although it was impossible to learn of anything out of the ordinary happening. Next a small gas meter was set up directly on top of the digester dome; the meter indicated a little gas. Then, 20,000 gal. of digester seed was hauled from the city sewage plant and pumped into the digester; but still there was no gas production.

A sample of the plant's digested sludge was taken and another small digester was set up. This digester immediately showed good gas production. It was then decided that there must be a leak in the gas line between the digester and the gas meter. After much digging a break eventually was found in the gas line about 6 ft. from the digester. All the gas had been going into the ground. After the gas line was repaired everything was normal.

Recently, the gas line to the waste gas burner became fouled. Upon digging it up it was found to have sagged about 6 in. and was broken in two places. The pilot gas line was also broken and leaking. Settling of the ground evidently caused these breaks; the water supply lines have broken several times.

The digester is of the floating cover type and has a screen-type supernatant selector. Despite this there usually is a poor supernatant from the digester because the solids will not settle, but stay in suspension. This is probably

caused by the greasy sludge pumped into the digester.

Toxic Wastes

About five years of experience using Daphnia for toxic wastes shows that if the wastes kill the Daphnia, the B.O.D. samples should be seeded. Chlorine in the water may also kill the Daphnia. It seems from experience that the Daphnia are a fairly reliable indication of toxicity.

During the warm months, or from May to late fall, the plant lawns are sprayed with unchlorinated final effluent. This keeps the lawns green and conserves water while also saving chlorine. About 100,000 g.p.d. are used on the lawns; this also reduces the B.O.D. input to the stream.

The waste treatment plant has done a good job since the change was made to two-stage filter operation. They recover fast if toxic or strong wastes come in. That such is the case is indicated by the fact that at times the grass has even been burned around the tanks by strong solvents, yet the filters have recovered quickly.

Grease or lard oil used as a defrothant in the antibiotic production seems to do the most harm. The oil stays in an emulsified form and passes through the sedimentation tanks. It then solidifies on the filter stones, especially during cold weather. This probably accounts for much of the solids build-up and ponding on the filters. Certainly the grease has definitely retarded B.O.D. reduction at times. A good percentage of the potential oil flow is being intercepted, either through elimination from the waste lines or by grease traps, but there is still further room for improvement.

B.O.D. Efficiency

Since the addition of the two-stage filters, B.O.D. reduction has been in the order of 95 to 98 per cent. The B.O.D. of both the influent and effluent of the plant are watched closely to keep the effluent within the allowable 100 lb. per day going to Portage Creek. Both cold weather and filter unloadings cut the plant efficiency. During these times relief is had by having a hauling contractor take care of the excess antibiotic spent beer if any needs hauling.

Plant Loadings

Plant loadings are as follows:

Raw influent B.O.D., 12-mo. avg.	3,080 lb./mo.
Raw influent B.O.D., summer months max.	3,800 lb./mo.
Raw influent B.O.D., winter months min.	2,000 lb./mo.
Raw influent B.O.D., last 12 mo. avg.	600 p.p.m.
Final effluent B.O.D., 12-mo. avg.	90 lb./day
Final effluent B.O.D., 12-mo. avg.	20 p.p.m.
Waste flow, 12-mo. avg.	600,000 g.p.d.

LIQUID WASTES CONTROL AT THE GENERAL ELECTRIC COMPANY RESEARCH LABORATORY *

By V. deP. Lukas and H. M. Ottaway

Sanitary Engineer, Plant Engineering and Maintenance Service, and Manager, Plant Facilities, Research Laboratory, respectively, General Electric Company, Schenectady, N. Y.

Research has been instrumental in producing a standard of living far beyond the three basic needs of man—food, shelter, and clothing. Industry derives its very lifeblood from research, and the national security depends upon it.

The home of the General Electric Research Laboratory is located on a knoll overlooking the Mohawk River, northeast of Schenectady. An aerial view of this completely modern scientific center dedicated to research is shown in Figure 1.

The work at the laboratory comes under three divisions:

1. Basic Research—the search for new knowledge with no special end or application in mind.
2. Applied Research—the search for new knowledge with a definite application in mind.
3. Development—the application of available knowledge to a definite problem.

There may be as many as 300 different projects going on with the help of every possible facility and utility available to the scientist. There are more than 10,000 instruments in stock and a staff of skilled technicians to repair and service them. If a scientist needs something that has not been built yet, a staff of craftsmen will construct whatever apparatus he may have in mind. In a glass shop, experts turn out specially blown apparatus for use in research. Standard utilities to all research rooms include hot and cold tap water, distilled water, gas, hydrogen, oxygen, compressed air, steam, and electric power at different voltages and currents. Laboratories, such as this one, are built by industry for the kind of action that makes for progress in research science to better the way of living.

At the Research Laboratory there is equipment for liquefying hydrogen and helium for conducting experiments near absolute zero, and there are high energy particle accelerators commonly called "atom smashers." Specialized equipment is needed for research; however, the laboratory still requires basic needs such as water and the disposal of wastes. This paper is concerned with the type of wastes, flow data, necessary treatment facilities, and some unusual operating experiences at the Research Laboratory.

Water Supply

The Research Laboratory purchases potable water from the Town of Niskayuna which, in turn, buys the water from the City of Schenectady. Average daily demand for 24 hr. is 500,000 gal. Maximum demand runs about 650,000 g.p.d.

Evaporative cooling, recirculation, and re-use of water are practiced when economical to do so. Water pumped from the Mohawk River is used for watering the lawns.

* Presented at the Spring Meeting, New York Sewage and Industrial Wastes Assn.; Lake Placid, N. Y.; June 17–18, 1957.

FIGURE 1.—General Electric Research Laboratory, Schenectady, N. Y.

Waste Chemicals

There are about 13,000 different chemicals on the shelves of the chemical stock room where the researcher may simply help himself. The quantities of chemicals used are so small and the variety so great that treatment is not necessary.

The easiest and most practical approach for disposal of most of these spent chemicals is to dilute them with the entire plant discharge. For occasional small quantities of water solubles, such as acids, alkalies, certain salts, acetone, and the lower alcohols, experience indicates that flushing down the drain preceded by and followed with an abundance of water can be employed. In other words, treatment by dilution in the total laboratory effluent is adequate, and additional stream dilution eliminates any detectible concentration of the materials in question.

There are limitations, however, to this dilution technique. Some chemicals develop hazards to personnel and property. The program of keeping objectionable chemicals out of the sewer system and equalizing those which can thus be discharged is under the control of and closely supervised by a safety supervisor. Experience at the Research Laboratory indicates that there are a number of chemicals which must be kept out of the sewer system or discharged with caution.

Completely water soluble solvents, such as acetone and ethanol, must be equalized in relatively large volumes of water to avoid flammable vapors which may cause fires in the sewer. A 4 per cent acetone solution has a flash point

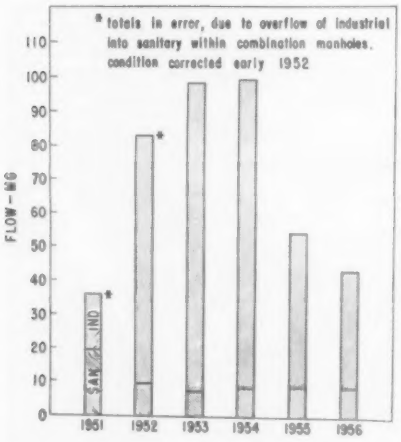


FIGURE 2.—Industrial and sanitary waste flows from the research laboratory.

at 120° F. This is more of a hazard than generally realized.

Not all acids should be discarded down the drain. Among these acids are: perchloric acid, fuming nitric acid, fuming sulfuric acid, and sulfan (SO_3). Perchloric salts react violently with water. The fuming acids also react violently with water, and the fumes emitted are toxic.

Water reactive liquids that should also be kept out of the drains are: acetic anhydride, acetyl chloride, chlorosilanes, bromine, S_2Cl_2 and $SOCL_2$, and dimethyl and diethyl sulfates. For instance, water and bromine react violently and the fumes can pass through the drain traps back into the laboratory rooms.

Another limitation of direct sewer discharge is the possibility of chemical action in the sewer. Highly dangerous products may be accidentally encountered, such as hydrogen cyanide formation from the mixing of cyanide salts with acids, or hydrogen sulfide production from reaction between sulfides and acids.

At the Research Laboratory chemicals that cannot be discarded down the drain are put into metal containers. The containers are removed daily and stored in fireproof boxes in the shipping area. The waste chemicals are taken to an isolated pit on the property and burned.

Laboratory Wastes

The chemical or laboratory wastes from all buildings, except one—the Combustion Building—are collected in a separate sewer. The average daily flow was 180,000 gal. in 1956. This was an average flow of 125 g.p.m., with peaks as high as 400 g.p.m. (Figure 2). During the latter part of 1951 and for the first two months of 1952, the laboratory wastes flow was spilling into the sanitary sewer.

Common manholes for the sanitary sewage and laboratory wastes were built. At one manhole, the laboratory wastes were discharging into the sanitary line through the clean-out plug. At another location, the concrete division wall was cracked and laboratory wastes were leaking into the sanitary sewer. These conditions were corrected as soon as the location of the difficulties was determined.

The chemical or laboratory wastes flow into an equalization tank. This tank was initially installed as a limestone neutralization tank. However, operating experience indicated that this was not required and it was converted into an equalization tank to help smooth out peak acid or alkali concentrations. The pH values of the tank effluent normally vary from 7.2 to 8.2. The effluent from the equalization tank then joins the treated sanitary sewage. This provides additional dilution for both wastes. The combined wastes then join with the stormwater flow which further dilutes the combined effluent of industrial and sanitary wastes before discharging into the Mohawk River.

The wastes from the Combustion Building drain into a reinforced concrete oil separator and then into a

small stream tributary to the Mohawk River. The oil is drawn off to a 275-gal. collecting tank, pumped into a tank truck, and disposed of at the dump.

Industrial Wastes Survey

Procedure

A comprehensive industrial wastes survey was completed in November, 1954. It was undertaken to demonstrate whether or not the laboratory was contributing materially to the pollution of the Mohawk River. The survey covered a five-week period beginning on a Monday and moving up one day each succeeding week. This approach insured covering routine operations during a normal week as well as any major variations in the wastes over an extended period of time.

Sampling "around-the-clock" was discontinued after the second day of the survey because the analytical results of the two days compared favorably and indicated little or no activity during the second and third shifts.

Analyses were made on all composite and grab samples, and included: pH, alkalinity as $CaCO_3$, cyanide, detergent, ether soluble matter, and chemical oxygen demand. The three-shift composite samples for the first two days were combined into a daily composite sample based on the volume of waste for each shift. Additional determinations were made on all the composite samples and on the daily grab samples that showed the highest concentrations in the analyses mentioned previously. These additional determinations included: suspended solids, total solids, chloride, sulfate, iron, copper, and chromium.

An observation of the physical appearance of the effluent was recorded as a standard procedure when collecting samples. Whenever the effluent was turbid or discolored, observation of the river at the outfall was made and recorded. Routine visual observations were made of the river hourly during the daytime.

Results

Spectrographic analyses were made on samples during the survey to determine what metals, particularly toxic ones, were present in the waste. The analyses covered examination for Mg, Ca, Fe, Si, Al, Ti, Zn, Cd, and Na. Magnesium and calcium were present in the greatest concentrations. They constituted approximately 90 per cent of the solids and originated primarily from the water supply. All other elements found were low in concentration. The quantities of some were so minute as to be impossible of determination by ordinary analytical methods.

The analytical results in Table I show that the basic requirements of quality standards for Class "B" waters were not exceeded.

All results, with one exception (copper content of 0.34 p.p.m.) found in one sample, were below the standards for a Class "B" stream. These results pertain to the laboratory waste effluent only and not the stream. After adequate mixing of the laboratory wastes effluent with the total flow from the laboratory, the copper concentration was well below the 0.2 p.p.m. standard before reaching the Mohawk River. This survey demonstrated conclusively that the laboratory was not contributing materially to the pollution of the Mohawk River.

River observations made during the

TABLE I.—Comparison of Results with Stream Standard

Determination	Analytical Data	Stream Standard*
pH	7.6 to 8.2	6.5 to 8.5
Cyanide (p.p.m.)	<0.1 p.p.m.	0.1 or less
Copper (p.p.m.)	0.14	0.2 or less
Zinc (p.p.m.)	Trace	0.3 or less
Cadmium (p.p.m.)	Trace	0.3 or less

* New York State Class "B."

survey indicated an occasional slight slick and a daily milky discoloration for a very short duration due to a slug of detergent. The worst condition reported during the five weeks was "slight suds downstream one-eighth of a mile." The detergent concentrations in the effluent were low and therefore would not have any deleterious effect on the receiving waters. Bathing was not impaired in the Mohawk River since all floating color disappeared within one-eighth of a mile. There are no known public bathing areas within three miles of the laboratory outfall.

Conditions have been much improved by changing the type of detergents used at the laboratory. Manufacturers of detergents are making great strides in producing non-frothing products.

A movie camera and timer were set up to monitor river conditions at the outfall. A frame a minute in color was taken during daylight hours over a three-day period. This is an excellent way of recording the physical conditions of a stream.

The survey confirmed the evaluation that dilution of the chemical wastes from the Research Laboratory yielded a completely satisfactory effluent and did not contravene Class "B" standards designated for the Mohawk River in the area of the discharge in accordance with the Public Health Law of New York State.

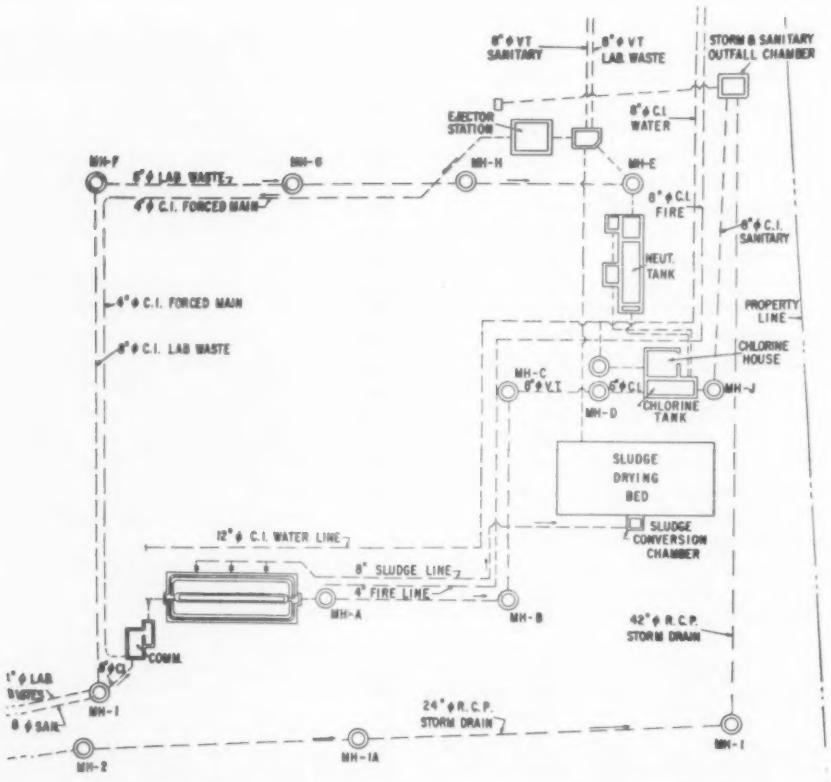


FIGURE 3.—Plan of the treatment facilities for sanitary and laboratory wastes.

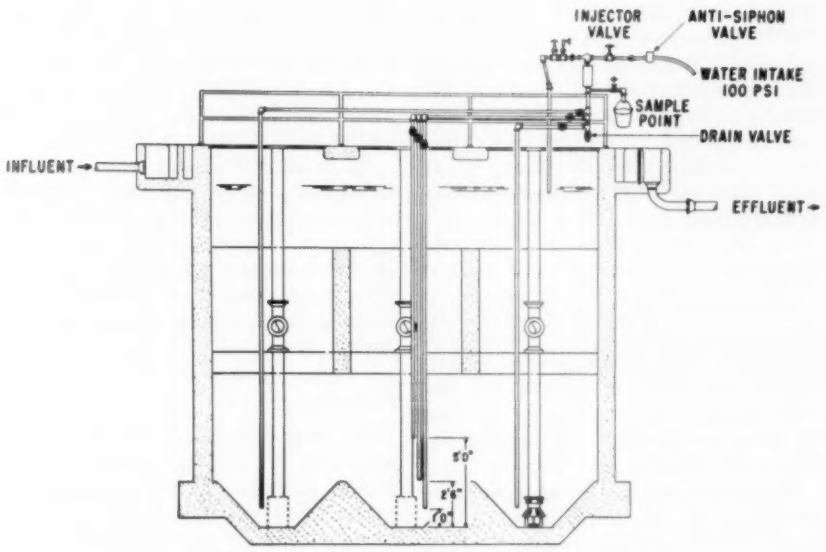


FIGURE 4.—Imhoff tank sludge sampling piping.

Sanitary Wastes

The sanitary sewage is collected in a separate sewer from all the buildings except the Combustion Building. The average flow is 30,000 g.p.d. or about 25 g.p.c.d.

The bar graph in Figure 2 shows a comparison of laboratory and sanitary wastes flows. Sanitary sewage averages 8 per cent and the laboratory waste about 79 per cent of the total flow. The term "industrial waste" is used broadly; it represents cooling and dilution water which contain small quantities of chemical wastes. The use of cooling towers and other water management practices, put into effect in 1955, resulted in a marked decrease in the flow of wastes.

A plan of the treatment facilities is given in Figure 3. The sanitary wastes flow through a comminutor and then to the Imhoff tank. The flow-through capacity of the tank is 7,600 gal., giving a detention time of about 2.54 hr. at the average flow of 3,000 gal. per hour. The sludge compartment has a capacity of 2,500 cu. ft. or sufficient storage for 203 days.

The effluent from the Imhoff tank flows into the chlorine contact where chlorination is provided during the summer months. The treated effluent combines with the industrial flow, and is discharged through a 42-in. storm sewer into the river.

At the Combustion Building, a septic tank has been provided, followed by a subsurface sand bed. The filter effluent then discharges into a small stream, which flows into the Mohawk River.

Treatment Plant Operation

The sewage treatment plant is routinely operated as other Imhoff tank installations.

Comminutor

The comminutor was taken out of service after nine months of operation because of the excessive maintenance costs. Small stones and other debris are carried to the comminutor causing

frequent replacement of the cutting blades.

Screenings amount to 3 to 5 qt. per day. The operator can clean the bar screens in a few minutes. The screenings are placed in a metal can to dewater and then put into a heavy paper bag. The screenings are disposed of by incineration.

Sludge

Determining sludge depths and sampling of the sludge in the Imhoff tank presented a little difficulty and the reliability was low. A method was developed for obtaining sludge samples by using an ejector. The piping arrangement is given in Figure 4.

Sludge samples can be taken at three elevations (1, 2½, and 5 ft.) from the bottom of the tank in the center section. Other samples are obtained from permanently installed pipes at the center of the end compartments 1 ft. from the bottom.

The whole operation is one of operating valves only. To draw sludge from the inlet compartment the suction valve between the chamber and the sludge compartment is opened, the drain and vent valves are closed, and the water is turned on. After about 3 to 5 min. the sound of the ejector changes. The sludge compartment valve is closed and then the water supply valve is closed. The vent valve is opened. The sample of sludge is then drawn from the chamber.

Some modifications such as a sliding pipe would make it possible to obtain samples from varying depths. Also the use of a section of clear tubing as part of the suction pipe would be helpful in determining sludge depths more accurately.

The hazards associated with a cross connection are minimized. An air space exists between the sample cylinder and the ejector, and siphon action ceases with a drop in water pressure. The sewage treatment plant operator disconnects the rubber hose after each use. The sewage treatment facilities are at a lower level, with more than 34 ft. of head available in the water mains at all times. For additional safety, an anti-siphon was installed.

In freezing climates, it is necessary to provide all piping with sufficient pitch to insure draining the lines after operations are completed. The valve on the discharge side of the ejector is installed so that back flushing of the chamber and piping is accomplished easily.

Sampling

The first two reports on the routine sampling in 1956 indicated the suspended solids and B.O.D. of the sewage to be twice the usual average. The sewage normally has an average concentration of 175 p.p.m. of suspended solids and 246 p.p.m. of B.O.D.

The sewage flowing into the Imhoff tank was amber in color with a solvent or soap aroma. Samples were collected at points in the sewer system serving the major areas to trace the source of material causing the color and high B.O.D. analysis. The cause of the high B.O.D. was found to be the pine oil used in the cleaning of the toilets. The pine oil is not a sanitizing agent, merely used as a deodorant. A sample of pine oil was diluted (1:50,000) with city sewage. The five-day B.O.D. was more than 393,000 p.p.m. Sampling procedure and the comminutor were the causes of the high suspended solids.

The use of pine oil and the comminutor have been discontinued. Good results are now obtained. Removal of suspended solids averages 62 to 73 per cent and the B.O.D. has been reduced 35 to 56 per cent.

Summary

Many new laboratories will be built by industries as more effort is put into research. Each will have specific chemical wastes and will require individual

evaluation to determine the best method for disposal.

In general, the easiest and most economical approach for the disposal of the small quantities of chemical wastes is by dilution. This practice, however, has limitations and all hazards to personnel and property must be evaluated and eliminated.

Research laboratories will generally be located in isolated areas and will require independent sewage treatment facilities. A sanitary sewage flow of 25 g.p.c.d. is a good basis for the design of the treatment units.

Although research has been instrumental in achieving a standard of living beyond the basic needs of man, there are still wastes which must be treated and disposed of.

Acknowledgment

The helpfulness of Mrs. Clarice Budnick, Howard H. Fawcett, and other General Electric Research Laboratory personnel is sincerely appreciated. Appreciation is also expressed to K. S. Watson for his comments and to C. E. Irving for providing fine service on running routine analyses.

DETERMINATION OF METHANE IN WATER

A proposed standard method for the determination of methane in water was reported on page 1077 in the August 1957 issue of the *Journal American Water Works Association*. The report was made by the Standard Methods Committee of AWWA. The methods included are a combustible gas indicator method and an Orsat method.

Publication of this proposed standard method has been made to encourage the broader use of the new methods with a view to learning their limitations. Other proposed standard methods for water analysis are to be published by AWWA as developed.

Comments, suggestions, and criticisms on this proposed methane in water determination are invited by the American Water Works Assn., 2 Park Ave., New York 16, N. Y.

AN INVESTIGATION INTO THE DISPOSAL OF BLOOD BY ANAEROBIC DIGESTION*

By Kelsie B. Singleton †

Superintendent, Sewage Treatment Plant, Kent, Ohio

The sewage treatment plant at Kent, Ohio, was faced with a rather unusual situation shortly after the dedication of the new plant in 1954. Located less than 100 yd. from the plant site is the Kent Provision Company, which slaughters approximately 300 head of cattle per week. The Provision Company had no means at that time for treatment of its industrial waste material. Consequently, paunch manure, blood, wash water, and sanitary wastes were discharged directly into the Cuyahoga River.

Because of the close proximity of the Provision Company to the sewage treatment plant, it was only natural that the possibility of treating the slaughter house wastes at the municipal plant should be explored. It was suggested by a consulting engineer that the raw blood might be treated best by pumping it directly into the heated digester at the sewage plant. The remaining wastes would be handled with the municipal sewage flow in the conventional manner.

As far as could be determined, there were no instances on record in which raw blood had been pumped into a heated digester. Since the sewage treatment plant had only one primary digester, an investigation was made on this method of disposal before anything was done on a larger scale that might interfere with normal plant operation.

Pilot Study

Two Pyrex jugs (20,000 ml. capacity) were selected for use as pilot digesters. The jugs were insulated from the laboratory bench surface and heated by an electric forced air heater. Provision was made for the continuous collection of evolved gas under water. When the collection tubes filled with gas the amount was recorded and the tubes were easily refilled with water by means of an aspirator. It was not necessary to disconnect any part of the apparatus. Thermometers were internally mounted and the temperature maintained at 95° F. With each daily addition of fresh solids to the pilot digesters the entire contents were gently stirred. Provision was also made for the withdrawal of supernatant at different time intervals. These pilot digesters were kept in operation on a 24-hr. basis.

To insure that these digesters would approximate closely the actual conditions in the plant primary digester, they were first charged with digested sludge in the same ratio as that usually stored in the primary. This sludge had the following analysis:

Solids (%)	9.3
Volatile solids (%)	50.4
pH	8.1
Alkalinity (p.p.m.)	2,820

Fresh solids were added every day to the pilot digesters in the same proportion as to the main digester. Since the main digester usually held 150,000 gal. and was charged at a rate of 4,000 gal. daily or about 3 per cent of the total contents, the pilot digesters were

* Presented at the 1957 Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conf.; Dayton, Ohio; June 19–21, 1957.

† Presently, Superintendent, Sewage Treatment Plant, Middletown, Ohio.

charged at 3 per cent of their 20,000-ml. capacity or with 600 ml. of fresh solids per day. These solids were taken daily from the raw sludge pumps at the time of charging the primary digester. In this way, variation in solids content from day to day could be eliminated because both the plant and pilot digesters were charged with the same fresh solids.

For the first 11 days both pilot digesters were charged with fresh solids only, to determine the gas production of each. Pilot digester No. 1 produced 28,000 cu. cm. of gas and pilot digester No. 2 produced 27,200 cu. cm., resulting in a difference of only 2 per cent.

The dosage of blood to be added was determined approximately. The slaughter house had an average kill of 300 head of cattle per week. Assuming 3.5 gal. of blood per head slaughtered (arrived at by actual measurement), the flow would total 350 gal. of blood per day for a three-day week, or about 9 per cent of the gallonage of fresh solids added daily to the digester. Proportioning this to the capacity of the pilot digesters meant that 54 ml. of blood would need to be added three times a week. The analysis of the raw blood was as follows:

Total solids (%)	26.2
Volatile solids (%)	97.5
Fixed solids (%)	2.5
B.O.D. (p.p.m.)	15,000

Blood was obtained from the slaughter house and kept from coagulating by the addition of minute quantities of sodium oxalate.

During a 24-day period a total of 14,400 ml. of fresh solids was added to each pilot digester. In addition, 715 ml. of raw blood was added to pilot digester No. 1. Pilot digester No. 2 served as a control.

Results

The results were startling! Gas production increased rapidly. Control digester No. 2 produced 58,336 cu. cm. and pilot digester No. 1 (charged with blood) produced 97,320 cu. cm. This was an increase of 67 per cent in gas production.

However, the carbon dioxide content of the gas in digester No. 1 went as high as 65 per cent, in contrast to 20 per cent in the control which was about normal for the plant. This high carbon dioxide content would render the gas unsuited to use in boilers and gas engines. The B.O.D. of the supernatant was 11,000 p.p.m. compared with a normal value of 5,000 p.p.m. in the control. This would create a terrific supernatant disposal problem for a primary-type plant. The total solids in the supernatant was 2.24 per cent compared with 0.36 per cent in the control. The supernatant was a red brown color and had an extremely objectionable odor, whereas the supernatant from the control digester was normal in every respect.

No attempt was made to determine the percentage of hydrogen sulfide present in the gas, but when the jugs were opened the odor was extremely strong. All of the odor was emanated from the pilot digester with the digesting blood. The odor was likened to decomposing blood mixed with a high concentration of hydrogen sulfide.

In the digested sludge, the per cent volatile matter was 60 per cent against 52 per cent in the control. The total solids were 10.6 and 7.6 per cent, respectively. The formation of foam and scum on the pilot digester with blood was almost three times as great as observed on the control.

Pilot digester No. 1 had no apparent settling of sludge nor separation into sludge and supernatant. The entire digester contents appeared as one homogenous mass, with an extremely thick layer of scum on top. By comparison, the control digester had the normal separation of sludge, supernatant, and light scum.

Conclusion

From this study, it appears that the addition of blood to an anaerobic di-

gester should be approached with extreme caution. The high percentage of carbon dioxide in the evolved gas, the high hydrogen sulfide content, the great B.O.D., the extensive scum and foam conditions, the indescribable odor, and the increased digestion time necessary to reduce the volatile matter in the sludge are all factors that indicate unsatisfactory digestion of whole blood. Some of the digester tests were repeated at a later date to verify the earlier data.

The Provision Company has installed a tank to catch all of the raw blood from the killing floor, which is then hauled away by a fertilizer company. The paunch manure is separated and conveyed to a dump truck for disposal by local farmers on their fields. A holding tank is now being installed to feed two vibrating screens to remove the major part of the settleable matter from the carcass wash water. The processed wash water will then be discharged to the Kent sewer system.

Although this experiment was not intended to be a research project, it indicates what even a small sewage treatment plant can do on a practical limited basis to study specific industrial wastes problems and how an industrial waste might effect normal plant operation.

OXYGEN RELATIONSHIPS IN STREAMS

A three-day seminar on oxygen relationships in streams will be held by the U. S. Public Health Service at the Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio, October 30 to November 1, 1957. Purpose of the meeting is to stimulate research through interchange of the most recent available information about problems related to the dissolved oxygen resources of streams.

Seminar topics for discussion are:

Use of stream data
D. O. requirements for fish
Oxygen sag
Stream reaeration
Organic sludge deposits
Waste mixing and diffusion
Impoundment effects
Sampling and analysis
Algae

Advance copies of the program and information about attendance may be obtained from the Director, Robert A. Taft Sanitary Engineering Center, 4676 Columbia Pkwy., Cincinnati 26, Ohio.

Stream Pollution

CHARACTERISTICS OF A STREAM COMPOSED OF OIL REFINERY AND ACTIVATED SLUDGE EFFLUENTS *

By F. J. Ludzack, Wm. Marcus Ingram, and M. B. Ettinger

Robert A. Taft Sanitary Engineering Center, USPHS, Cincinnati, Ohio

A previous report (1) described the behavior of aerobic mineral oil emulsions and the effects of variables such as temperature, agitation, and seeding on the biochemical assimilation of oil. Oil sedimentation was inhibited by air recirculation in the laboratory test units in order to maintain availability of a greater proportion of added oil for aerobic action. The laboratory data pertain to suspended oil, whereas emulsified surface and settleable oil may occur in a stream.

This report presents observations on the behavior of a stream containing refinery effluent. Observations were made on physical, chemical, and biological characteristics associated with the relatively nonvolatile hydrocarbons in the stream. Wide variations in conditions were assured by making observations at different seasons over a 15-month period. The main objective was to acquire a better understanding of the effects of oily wastes on stream behavior.

Stream data were obtained on a section of the Ottawa River from Lima, Ohio, to the confluence of the Ottawa and Auglaize Rivers. Figure 1 shows the section involved including stream elevations and mileage from the mouth.

Lima, Ohio, water requirements are such that the entire river flow may be pumped to the water reservoirs above Mile 36.8 (Figure 1). Under these conditions, waste from the Lima area receives little dilution in the river. Effluent from the city activated sludge treatment plant located at Mile 33.0 may be pumped upstream and released near Mile 36.0 to flush the river channel during low flow. A series of dams between Mile 36.8 and Mile 33.1 divide the river into several pools and confine activated sludge effluent to the channel below Mile 36.8. Domestic and industrial waste-flow to the river within Lima is considered relatively small except during emergencies such as storms, line breaks, or pump failure.

Petroleum refinery effluent enters the river below the dam at Mile 33.1. Refinery process wastes are treated in a modified A.P.I. separator. Sanitary wastes from the refinery are treated separately by the activated sludge process. The combined wastes consist primarily of emulsified hydrocarbons and associated substances that are not readily separated by gravity.

A petrochemical plant is located adjacent to the refinery. Its effluent passes through a pond with about three days detention and enters the river at Mile 32.0. Products include ammonia, urea, carbon dioxide, and nitrous and nitric acids; all were in production after May, 1956. Influence of the petrochemical plant effluent in the stream was considered of secondary importance during this study except as it may have affected refinery effluent behavior.

Dry weather flow in the river below

* Presented at the 1957 Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conf.; Dayton, Ohio; June 19–21, 1957.

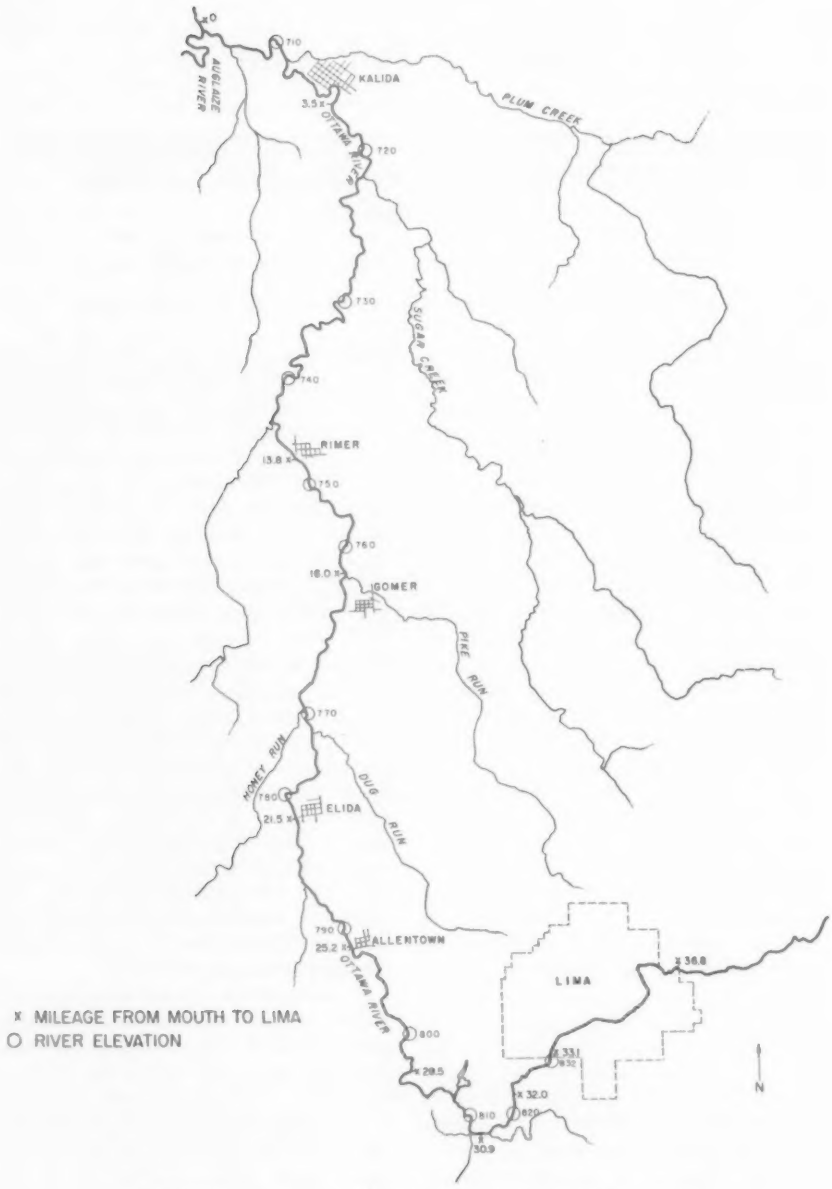


FIGURE 1.—Ottawa River from its mouth to Lima, Ohio.

Mile 33.1 consisted mainly of 3.1 to 6.1 c.f.s. of refinery effluent, 12.3 to 18.5 c.f.s. of activated sludge effluent from the City of Lima, and after May, 1956, 1.6 to 2.3 c.f.s. of petrochemical plant effluent. Creeks emptying into the river from Mile 33.1 to Mile 21.5 had a negligible dry weather flow. A

large number of residences, a state hospital, a country club, and a boys' home contributed an undetermined amount of untreated or partially treated waste between Mile 32.0 and Mile 28.5. There were no known sources of industrial waste below Mile 32.0.

Observed sections of the Ottawa River below Mile 33.1 varied in depth from 3 in. to 6.5 ft. during dry weather. Most of the river had a depth of less than 18 in. The stream flowed over rock, gravel, and clay formations, with clay more evident near the mouth of the river. River elevations in Figure 1 are from U. S. Geological Survey data and indicate stream gradients in terms of 10-ft. contour intervals. The highest gradient was located in the first two miles below Lima.

Time of passage in the river was determined by comparative study with radioactive tracer, dye, salt, and floats (2). River flow was 19 to 21 c.f.s. during passage-time measurements. This flow included the average of the range from 18 to 23 c.f.s. for dry weather conditions. The best available estimate of passage time in hours and minutes from the activated sludge effluent outfall (Mile 33.0) to each of the indicated points was:

Modal Flow Time *

To Mile 32.0	4 hr. 15 min.
To Mile 31.1	10 hr. 15 min.
To Mile 28.5	21 hr. 30 min.
To Mile 25.2	35 hr. to first arrival of dye.

* Rb^{86} data on all stations except Mile 25.2 (2).

USGS gauging station records show a highly variable flow during rainy weather.

A preliminary reconnaissance was made for each survey to locate significant changes in pollution and to select appropriate sampling stations; following this, samples were collected and observations recorded.

Liquid samples were obtained from the main channel at least 3 in. below the surface to avoid film or scum. Sludge samples were obtained by carefully scraping the bottom, discarding rock, wood or other extraneous material. Oil film or scum on the surface was noted but not sampled.

Oil determinations on liquid samples were made as described by Ludzack and Whitfield (3). This method made it possible to determine saturated hydrocarbons exclusive of interference from vegetable or animal oils, fatty acids, or other extractable oxygenated materials. Aromatic hydrocarbons and constituents having a volatility equal to or greater than that of kerosene were not recovered quantitatively.

Sludge samples were filtered through paper, dried over night at 75° C. and extracted with a Soxhlet apparatus. The extract was analyzed by infrared as in liquid sample technique. Sludge immediately below the refinery outfall contained oil that passed through the filter paper. Two results were reported for this type of sample, one by wet extraction of the filtrate, and one for the dry sample.

Results of Visual Observations

Conditions encountered during hot, dry weather (June, 1955) are summarized in Table I. A variety of organisms was lacking in the stream from Mile 33.1 to Mile 25.2; in the zone of sludge deposition, plankton were dominant. The first significant variety of pollution-tolerant organisms was found at Mile 16; clean water organisms were established at Mile 3.5. Odor and appearance of the water were noticeably better when stream velocity was high enough to prevent sedimentation. Near the refinery the water had a milky appearance; brown suspended material appeared in the water at Mile 32.0. Suspended material was dark green or black at Mile 30.9. The milky appearance disappeared by the end of the first mile of travel.

A second survey (August, 1955) is reported in Table II. Heavy rains had flushed the channel of old sludge

TABLE I.—Visual Observations of the Ottawa River (June, 1955), Survey No. 1

Sample Location	Biological Growth	Water	Bottom	Banks	Surface
Mile 33.5	Plankton, crustacea and insects abundant	Mild sewage odor; light green color	Black muck	Grassy	Some algal rafts
Refinery effluent	Not apparent	Oily odor; slightly turbid	Black oily solids	Oil coated	Discontinuous oil film and scum
Mile 32.0 to 25.2	Abundant plankton growth	Oily, sewage odor; soupy, dark color	Oily sludge in pools	Oil coated	Algal rafts, oil film and scum
Mile 21.5	Plankton reduced, higher aquatic plants, and worms	Slight sewage odor; fairly clear	Rocks algae coated; little sludge	Some black sludge	Oily haze
Mile 16.0	Bloodworms dominant; first good variety of pollution-tolerant organisms	Clear	Brown floc	Some black sludge	Clean
Mile 3.5	Crayfish, diatoms, fish, fresh water mussels, mayflies, caddis worms, etc.	Crystal clear	Silty; earthy odor	Sand or silt	Clean

prior to the observations. The river level had fallen almost to that of June (20.5 c.f.s.). Refinery effluent appeared to have more surface oil and scum. Turbidity in the river was greater. At Mile 33.1 turbidity obscured visibility of bottom objects at 6 to 8 in. of depth. Conditions changed rapidly so that at Mile 28.5 bottom objects could be seen at depths of 30 in. or more.

Sludge deposition followed a distinctive pattern. A thin, oily, black sludge was apparent within 300 ft. of the refinery outfall. Only small quantities of sludge were found in pools located from Mile 33.0 to Mile 32.0. Gross sludge deposits were present from Mile 32.0 to below Mile 30.9.

On the basis of water appearance and biota the stream appeared to recover as much in 8 miles of flow during August as it had in 17 miles during June.

Table III shows observations for the third survey (January, 1956). The river had not been flushed since November, 1955. No water was being pumped from the river above Mile 36.8, hence dry weather flow plus the various effluents were included (30 c.f.s.). River temperatures were low enough to permit formation of an ice cover above Mile 33.1. Refinery and activated sludge effluents warmed it from close to 0° C. at Mile 33.1 to 13° C. at Mile 32.0. The temperature was 8° C. at Mile 28.5, 3° C. at Mile 25.2, and was low enough for an ice cover below Mile 16.0. Compared with summer observations, there was a much slower change in the river as it flowed down stream. Emulsified material and suspended

TABLE II.—Visual Observations of the Ottawa River (August, 1955), Survey No. 2

Sample Location	Biological Growth	Water	Bottom	Banks	Surface
Mile 33.5	Mosquito larvae, plankton, worms, physid snails	Slight sewage odor; turbid; gray-green	Muck	Grassy	Some froth
Refinery effluent	Not apparent	Oily; slightly turbid	Oily solids below outfall	Oily coating	Oil film and scum
Mile 32.0 to 30.9	Plankton abundant	Oily, sewage odor; turbid, dark color	Black, oily sludge	Thin oil deposit	Oily film and brown scum
Mile 28.5	Plankton and numerous algal filaments on rock	Slight odor; clear, amber color	Oil coated rock; little sludge	Algal coated; oily	Trace of oil film
Mile 25.2	Mosquito larvae, algal mats and filaments	Amber, clear; odor not apparent	Brown floc	Oily sludge	Clean

TABLE III.—Visual Observations of the Ottawa River (January, 1956), Survey No. 3

Sample Location	Biological Growth	Water	Bottom	Banks	Surface
Mile 33.5	Ice covered	—	—	—	—
Refinery effluent	Not apparent	Oily odor; slightly turbid	Black, oily solids below outfall	Thin oil cover	Oil film and scum
Mile 32.0 to 30.9	Gray filamentous growth and thin algal layer on rock	Slight oily, sewage odor and turbidity; dark color	Brown floc, some black sludge	Oily	Continuous oil film, some scum
Mile 28.5	Similar to the preceding	Slight oily, sewage odor and turbidity; clearing	Brown floc, some black sludge	Fairly clean	Oil film decreasing
Mile 25.2	Algae, sphaerotilus, and fungi more apparent	Clearing	Brown floc	Some black sludge pockets	Oily haze
Mile 16.0	Ice covered*	—	—	—	—

* Water still turbid before entering the iced zone.

solids decreased slowly; there was little sludge deposition.

A fourth reconnaissance was made during March, 1956. The sewage treatment plant was shut down for annual inspection and repair. The river level was sufficiently high so that the surface velocity as estimated by floats was about six times that during August, 1955. Chloride concentrations indicated about 30 to 1 dilution of refinery effluent in the stream. Changes in pollution were difficult to detect because of the high flow and silt content. A surface oil film was the main evidence of contamination. The film persisted with little evident change from Mile 33.1 to below Mile 13.8.

Observations for the fifth survey were made late in September, 1956 (Table IV). The flow in the river (18.5 to 18.0 c.f.s. for at least two weeks preceding observation) was the lowest encountered. Refinery effluent volume was also lower (2.9 c.f.s.). Bottom plant growth was breaking loose and decaying as if influenced by the cooler weather. River temperatures

TABLE IV.—Visual Observations of the Ottawa River (September, 1956), Survey No. 5

Sample Location	Biological Growth	Water	Bottom	Banks	Surface
Mile 33.5	Blue green algae chironomid worms and physid snails	Clear	Gray to black muck	Like cracked sludge cake	Occasional algal mats
Refinery effluent	Not apparent	Turbid	Black, oily solids	Thin oily cover	Trace of oil film
Mile 32.0	Algae on bottom and left bank	Brown with susp. solids	Rocks had an oily odor; little sludge	Algal cover on left bank; thin, brown, oily deposit	Trace of oil film and scum
Mile 30.9	Blue-green algae on bottom and banks	Gray; turbid	Little sludge; rocks had oily, sewage odor	Algae and brown oil deposit	Trace oil
Mile 28.5	Algae and surface beetles	Clear	Algal streamers; oily, clay sediment in backwater	Oily clay muck at the left bank	Clear
Mile 25.2	Mosquito wrigglers at margins; also surface beetles, small amount of algae	Silty	Brown floc	Oily clay muck	Clear
Mile 16.0	Algae, chironomid worms, beetles, physid snails	Clear	Sand and gravel	Marginal oily clay	Clear
Mile 3.5	Crayfish, gill breathing snails, duckweed, stonefly larvae, diatoms, unionidae clams	Clear	Sand and clay; earthy odor	Marginal oily clay	Clear

TABLE V.—Oil Content of Liquid Samples from the Ottawa River

Sampling Location	Survey No. 1 June, 1955		Survey No. 2 August, 1955		Survey No. 3 January, 1956		Survey No. 4 March, 1956		Survey No. 5 September, 1956	
	Oil* (mg./l.)	Hc/Hc+Ox (%)	Oil* (mg./l.)	Hc/Hc+Ox (%)	Oil* (mg./l.)	Hc/Hc+Ox (%)	Oil* (mg./l.)	Hc/Hc+Ox (%)	Oil* (mg./l.)	Hc/Hc+Ox (%)
Mile 33.5	2.4	25	2.9	14	—	—	2.0	10	1.8	11
Refinery effluent	28.5	86	50	90+	55	90+	54†	90+	57	90+
							50			
Mile 32.0	—	—	3.5	75	8.0	55	2.3	18	4.1	46
Mile 30.9	—	—	1.9	21	7.5	50	—	—	2.7	17
Mile 28.5	3.8	29	1.1	18	5.2	37	—	—	2.8	9
Mile 25.2	—	—	1.1	18	4.1	7	—	—	2.1	14
Mile 21.5	6.6‡	25	—	—	—	—	—	—	—	—
Mile 16.0	3.2	25	—	—	—	—	—	—	—	—

* As an octadecane equivalent absorption by infrared. Includes hydrocarbons and oxy compounds.
† Two samples on different days.
‡ Sample taken in a riffled section.

were 23° C. to 17.5° C., with the higher temperatures near Lima. Animal life was relatively scarce although a good variety was present at Mile 3.5.

Physical condition of the river was better than usual. Surface oil was limited to trace quantities; sludge was not apparent in the locations where it was found in warm weather. Bank deposits indicated substantial oily material but it appeared to be from old deposits. Stringy and flocculent brown solids appeared in the flow at Mile 32.0; at Mile 30.9 the color of the water was a turbid gray. Oil and sewage odors were relatively mild compared to warm weather observations. The water was clear by the time it reached Mile 28.5. The petrochemical plant effluent (pH 9.2) had a marked effect on the river alkalinity and raised the pH from 7.5 to 8.6; this value did not decrease in the next 15 miles of travel.

Oil Content of Liquid Samples

Table V shows the results on liquid samples obtained during each reconnaissance in terms of the equivalent infrared absorption of octadecane. The first column shows the milligrams per liter for the mixed extract; the second, the percentage of saturated hydrocarbons in the extract. During warm weather the oil content of the flowing water rapidly approached values comparable with those above Mile 33.1. In cold weather the approach was more gradual. The percentage of hydrocarbons decreased more rapidly than the mixed extract concentration.

Figure 2 shows the variation in hydrocarbon content versus downstream mileage for three of the surveys. The concentration of oil listed for Mile 33.1 was not determined directly because of questionable mixing of effluent in the river. It was calculated from data on the flow of the refinery effluent and stream, and from the respective concentration of hydrocarbons in each. Flows were obtained from a Parshall flume recorder on the refinery outfall channel and a USGS control section in the river at Mile 25.2. Extract concentrations

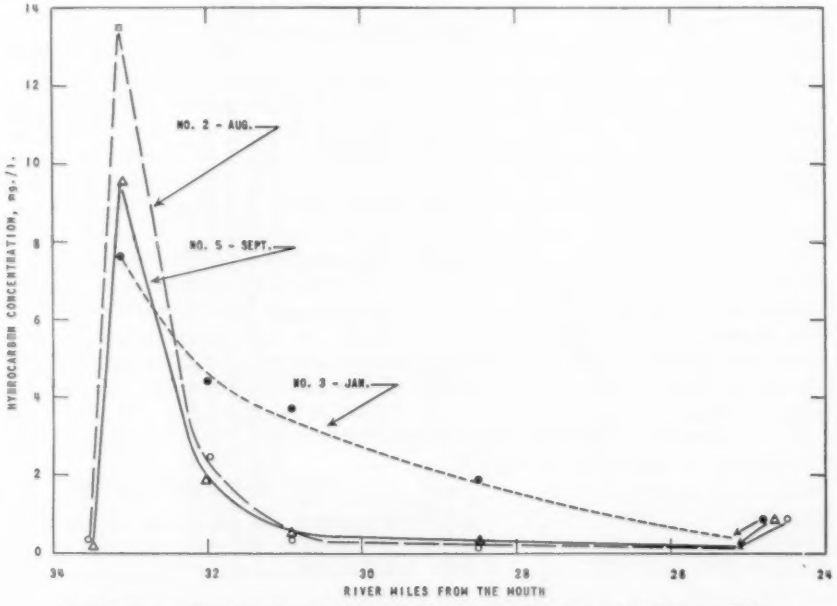


FIGURE 2.—Hydrocarbon content of liquid samples from the Ottawa River.

TABLE VI.—Oil Content of Sludge Samples from the Ottawa River

Sampling Location	Survey No. 1 June, 1955		Survey No. 2 August, 1955		Survey No. 3 January, 1956		Survey No. 4 March, 1956		Survey No. 5 September, 1956	
	Oil* (%)	He/He+Ox (%)	Oil* (%)	He/He+Ox (%)	Oil* (%)	He/He+Ox (%)	Oil* (%)	He/He+Ox (%)	Oil* (%)	He/He+Ox (%)
Mile 33.5	0.35	35	0.6	90+	Ice cover		Channel clear		0.5	90+
100 ft. below	17.8	85	8.0	90+	8.5	90+	Channel clear		5.9	90+
ref. outfall	2.2†	90+	3.0†	90+	9.1†	90+			—	—
Mile 32.0	—‡	—	1.2‡	90+	8.7	90+	Channel clear		3.1¶	90+
Mile 30.9	—‡	—	5.2‡	90+	5.9	90+	2.8	90+	2.5¶	90+
Mile 28.5	2.0‡	75	6.9	90+	16.1	90+	Channel clear		2.4¶	90+
Mile 25.2	—‡	—	0.6	90+	11.2	90+	2.4	90+	4.1¶	90+
Mile 21.5	2.4	44	Channel clear		Channel clear		Channel clear		Channel clear	
Mile 16.0	0.5¶	81	Channel clear		Ice cover		Channel clear		Channel clear	

* As an octadecane equivalent infrared absorption on the mixed extract, dry solids basis.
† Filterable oil obtained by wet extraction as a per cent of the dry solids retained.
‡ Locations where oily sludge (in pooled areas) was more than 6 in. deep.
¶ Bank deposit (channel deposit negligible).

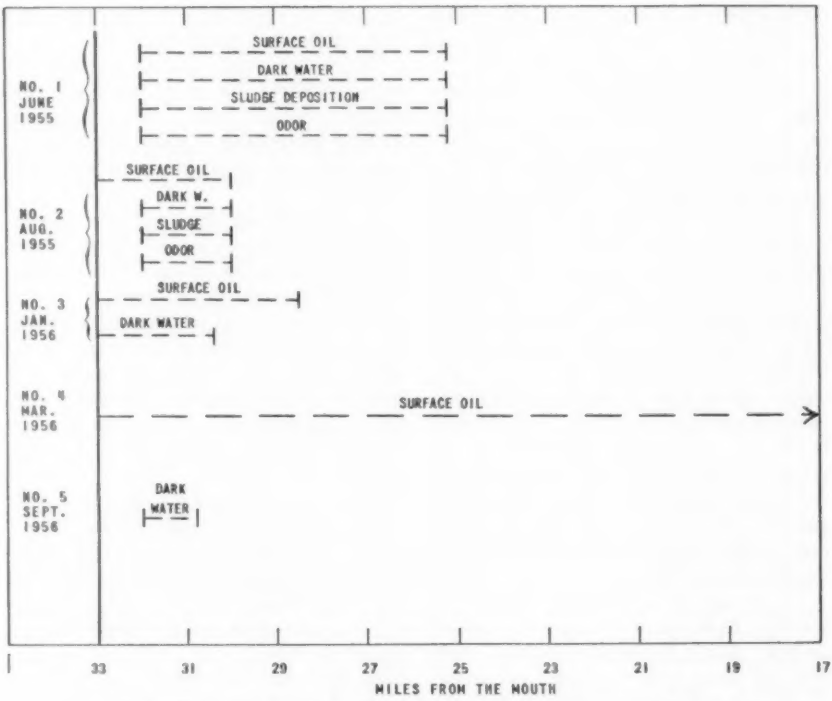


FIGURE 3.—Visual characteristics of Ottawa River conditions.

and percentages of hydrocarbon were obtained from Table V.

Figure 2 shows that the hydrocarbon content of the flowing water was reduced at least 80 per cent in approximately one mile of flow during August and September, 1955. A 40 per cent reduction occurred in the same distance during January. After eight miles of flow the values reached a common level almost identical to that above Mile 33.1. The curves illustrate the rapid separation of emulsified oil from the water. Material losses shown would appear as hydrocarbons on the bank, in sludge, as surface film or scum, and in oxidation products.

Sludge Sample Results

Table VI shows the oil content of sludge samples on a dry solids basis. The percentage of hydrocarbon was high in the mixed extract in nearly all samples. The reference to 90+ per cent hydrocarbon is a conservative estimate used whenever the infrared curve indicated little absorption due to oxygenated materials. The samples were not chromatographed unless a significant absorption not attributable to hydrocarbons was obtained.

Oxygenated materials either were eluted from or digested within the sludge mass. Elution appears more likely as the percentage of oxygenated materials did not increase during cold weather when the digestion rate would be lower. The high proportion of oxygenated materials in liquid samples supports the same implication.

Sludge deposits close to the refinery were considered to account for a minor fraction of the effluent oil; this material covered only a small area with thin deposits. The first gross deposits were found near Mile 32.0. Several

pools between Mile 33.1 and Mile 32.0 afforded ample opportunity for deposition; evidently the oily solids were not in condition for deposition in this section. Heavy deposits were found only in warm weather and at locations reported in Table VI and Figure 3. The settled material had a black, graphite-like appearance, was easily disturbed, and traveled some distance before resettling. The tendency to lift and resettle apparently enabled the sludge to spread over a greater section of the river during long periods of dry, warm weather. (See survey No. 1.) Since recent rains had flushed the channel prior to survey No. 2, the deposits were localized. Spreading appeared to be related to anaerobic gas formation by the sludge mass which lifted the sludge and moved it in a downstream direction. This action was not established during survey No. 2.

There was an appreciable difference between channel and bank deposits of sludge. Bank deposits contained more silt and sand with a lower proportion of oil and putrescible material. Flushing rains had relatively little effect on their movement, but readily moved the channel deposits.

Discussion of Results

Figure 3 shows the variability in observable characteristics of the river at different seasons and flow distances. Zones were not as precisely defined as the chart indicates, but an idea of the gross characteristics of the stream at different seasons can be obtained.

The difference in gross pollution zones between surveys Nos. 1 and 2 was relatively great, as previously discussed. The chart shows that some flow distance was required for the visual evidence of pollution to become established during warm weather. Cool weather caused more surface oil and less sludge, as indicated by surveys Nos. 3 and 4. Observations made during the fifth survey were not comparable with preceding observations, due in part to lowering temperatures, less oily waste, and other factors.

Whenever thick sludge deposits occurred (Table VI and Figure 3), turbidity, color, odor, and plankton growth were more evident. Surface oil appeared to be a more independent variable.

A definite sequence of events appeared to follow introduction of oil emulsions into the stream. Oil globules from emulsions were trapped in the biological material which agglomerated into a settleable floc and carried the oil down with it. Settled solids quickly became anaerobic after deposition during warm weather. Sludge gasification tended to raise both oil and solids toward the surface, with the solids tending to resettle after the gas bubble broke through the water surface.

The net result was a fairly rapid physical separation of the emulsified oil from the flowing water. Most of the oil was stored in sludge banks during warm weather. The dynamic equilibrium between suspended and sedimentary oil resulting from sludge gasification provided a slow feed-back of oil to the flowing water. Turbulence tended to increase the feed-back and could result in a flush-out of the easily dislodged sludge.

In laboratory studies (1) 50 to 80 per cent of mineral oil emulsions were biologically destroyed per week under aerobic conditions at summer temperatures. No action was detectable at 4° C. either with respect to physical separation or assimilation. Stream results indicated a more rapid physical separation; it is possible that biological assimilation also was more rapid in the stream, but it is unlikely that assimilation caused the oil loss represented in Figure 2, because it occurred within approximately a 4-hr. passage time.

With much of the oil in the Ottawa River held for substantial periods in anaerobic bottom deposits, possible anaerobic assimilation of oil becomes important. Beerstecker (4), ZoBell (5), and others cite data indicating that

microbiological metabolism of hydrocarbons can occur under anaerobic conditions. Assimilation of low molecular weight hydrocarbons appears to be significant. Hydrocarbons with a chain length of 12 carbons or more appear to be attacked very slowly if at all (4) (5).

There was evidence of anaerobic digestion in the river sludge deposits as evidenced by general appearance, gasification, and sulfurous odor. Oil decomposition could not be followed in the stream because of the transient nature of the deposits. Laboratory work was undertaken to investigate further the possibility of measureable anaerobic assimilation of the nonvolatile mineral oil.

Samples of river sludge and of partially digested sewage sludge were isolated in the laboratory with oil added when necessary to bring the initial oil concentration up to 1,500 to 2,000 mg./l. Paired units of each type were incubated under anaerobic conditions at 5°, 20°, and 35° C. One of each pair was dosed with 2 per cent by volume of sewage each day. Oil determinations were made at weekly intervals for 125 days.

Gas production, decrease in volatiles, and microorganism populations indicated continuing activity in the digesters. The sewage-dosed samples were appreciably more active in gas production throughout the observed interval. Higher temperatures resulted in more gas and a greater decrease in sludge volatiles. There was no evidence to indicate a significant biological degradation of hydrocarbons. Regression line slopes over the four-month period averaged about 1 per cent loss of oil per week after correction for sampling loss. No difference in hydrocarbon loss that could be attributed to seeding or temperature was detectable. Since the average loss was small compared to the coefficient of variation of the sludge oil analysis (9 per cent), the results give further indication that anaerobic decomposition of hydrocarbons in the river sludge banks is not significant.

The high ash content of Ottawa River sludge suggested that silt was involved in sludge sedimentation. Clay and clay-like materials were investigated in the laboratory for clarification and oil removal. A series of different preparations showed no value when used on oil in water emulsions. However, in the presence of flocculent biological materials the clay and oil were similarly trapped in the mass. The higher density resulted in better settleability of the combination. Apparently Ottawa River silt increased the sedimentation rate in the river by weighting the flocculent solids and oil.

Reports on the Ottawa River from the Lima Department of Utilities (daytime samples) rarely show less than 2 mg./l. of dissolved oxygen at downstream stations during warm-weather low flows. Nocturnal oxygen levels are unknown but riffled sections of the stream probably contribute some oxygen to the river at night. Plankton growth would tend to widen the diurnal gap between high and low oxygen content. The combined effects should maintain oxygen levels suitable for aerobic oxidation of hydrocarbons for a major part of each day.

The petrochemical plant contributed significant quantities of ammonia and organic and oxidized nitrogen to the stream during survey No. 5. For example, the river from Mile 30.9 to Mile 16.0 showed a range of 41 to 80 mg./l. of ammonia-nitrogen, 33 to 15 mg./l. of organic nitrogen, and a relatively constant 14 mg./l. of oxidized nitrogen. The petrochemical plant effluent showed behavior indicative of bacteriostatic action when B.O.D. tests were made. Stream dilution tended to eliminate this effect, but B.O.D. reductions on survey No. 5 were less with downstream distance than during earlier surveys. Small concentrations of copper and lead were found in the petrochemical plant effluent on semi-quantitative spectrographic analysis.

The data presented have clearly demonstrated a major removal of oil in a relatively short stretch of river during warm weather. However, the evidence collected strongly indicated that the bulk of the oil is not biologically assimilated, but is stored as oily sludge on the river bottom and flushed from the river bed by periodic river rises.

The retained oily sludge cannot be regarded as harmless. It represents pollutional material which may collect over a long period of time and it must be recognized that such material is capable of causing severe damage to legitimate water use. Bottom sludges such as those observed are believed to be responsible for the extreme impairment of water quality which sometimes occurs when a river flush-out follows a long period of low flow.

Summary and Conclusions

During dry weather flow conditions the stream investigated consisted primarily of municipal secondary treatment effluent, refinery effluent, and during the last few months of study, petrochemical plant effluent. The mixture would appear to provide the necessary microorganisms and supplementary minerals for comparatively rapid biological action if toxicity was not serious. This northwestern Ohio stream has certain unique characteristics, but in all probability its behavior would be similar to river behavior in other situations except for a different rate and degree of change.

The primary problems in this stream were those relating to the behavior of oily sludge. Gross pollution effects were more pronounced in the vicinity of sludge deposits. Little degradation of oil could be demonstrated in the anaerobic sludge mass. Although a slow feed-back of oil from the sludge to the flowing water occurred during warm, low flow periods, only a small proportion of the total oil was available for aerobic decomposition. High flow or other turbulence readily moved the deposited material downstream.

River conditions could be highly unfavorable during the initial stages of a flush-out as disturbed sludge added its oil, oxygen demand, and solids load to the flow. Although this condition was not observed in the field, it would be likely to vary in intensity with the rate of flow rise, dilution, and water temperature. Effects upon redeposition would depend on the age and activity of the sludge as well as the deposition area.

Physical entrapment of emulsified oil globules in biological material appeared to be related to the emulsion break in the stream and to the formation of sludge deposits. Time and temperature appeared to be a factor in this phenomenon since settling did not occur immediately after mixing; it occurred more rapidly at high summer temperatures when biological action was greater. Silt apparently weighted the biological materials and oil, causing the agglomerated mass to settle more readily.

Mineral oil content of the flowing water below the refinery rapidly approached values similar to those above the refinery. In one mile of flow under summer conditions about 80 per cent of the oil separated; during the winter about 40 per cent separation occurred in the same distance (passage time approximately 4 hr.). After eight miles of flow the mineral oil content of the flowing water was comparable to upstream samples during winter or summer conditions. Separated mineral oil appeared as surface film, sludge, boundary deposits, and probably some degradation products.

Laboratory results show that mineral oil decomposition by aerobic biological action amounts to 50 to 80 per cent per week at summer temperatures. No assimilation was detectable at near-freezing temperatures. It was not possible to determine the extent of oil assimilation in the stream. The oil sepa-

ration occurred in a short flow time leaving relatively little suspended or surface oil available for aerobic assimilation. It is not likely that a high percentage of oil could have been biologically assimilated upstream of Mile 25.2.

Acknowledgments

Many industrial, state, and municipal officials and their staff members gave wholehearted support to this investigation. Following is a partial enumeration of those who made contributions in time, material, and information: Bruce E. McDill, H. P. Cowgill, and C. E. Lay, Sanitary Engineers, Ohio Department of Health, Columbus, Ohio; E. E. Smith,* Director of Utilities, and W. H. Jacobs, Superintendent, Sewage Treatment Plant, Lima, Ohio; R. N. Simonsen, Process Engineering Division, Ohio Oil Co., Cleveland, Ohio; and V. V. Wellman, and L. J. Ninde, Process Engineers, Lima Refinery, Ohio Oil Co., Lima, Ohio; and D. C. Stoll, Technical Superintendent, Petrochemicals Plant, Lima, Ohio. R. N. Bloomhuff assisted in sample collection and analytical work during the project.

* Deceased, September, 1956.

References

1. Ludzack, F. J., and Kinkead, D., "Persistence of Oily Wastes in Polluted Water Under Aerobic Conditions." *Ind. Eng. Chem.*, **48**, 263 (1956).
2. Straub, C. P., Ludzack, F. J., Hagee, G. R., and Goldin, A. S., "Time of Flow Studies—Ottawa River, Lima, Ohio." Presented at the American Geophysical Union Meeting, Washington, D. C. (Apr. 29–May 1, 1957).
3. Ludzack, F. J., and Whitfield, C. E., "Determination of High Boiling Hydrocarbons in Polluted Water." *Anal. Chem.*, **28**, 157 (1956).
4. Beerstecker, E., "Petroleum Microbiology." Elsevier Press, New York, N. Y. (1954).
5. ZoBell, C. E., "Action of Microorganisms on Hydrocarbons." *Bact. Rev.*, **10**, 1 (1946).

AVAILABLE FILM

A newly released 20-min., sound, color film describes construction techniques for clay pipe sewer systems. Titled, "Here's How, With Clay Pipe," the movie presents in actual location sequence such basic steps as excavating, sheeting and bracing, bedding, laying, jointing, and backfilling.

Considered good media for engineers' meetings, water and sewage works conventions, inspection crews and engineering classes, the movie may be booked without obligation by writing to Robert Scott, Clay Products Association, 100 North LaSalle St., Chicago 2, Ill.

THE OPERATOR'S CORNER

CONDUCTED BY DONALD P. SCHIESSWOHL

INITIAL DIGESTER START-UP AT ALEXANDRIA, VIRGINIA

BY S. W. SHAFER

Superintendent of Operations and Maintenance, Alexandria, Va., Sanitation Authority, Alexandria, Va.

The early establishment of alkaline sludge digestion with the resulting production of gas suitable for use as fuel for the engines powering the main sewage lift pumps was a principal objective in plans for placing the Alexandria, Va., high-rate trickling filter plant in operation in July, 1956. A digester start-up plan that had produced successful results at other installations was adopted. Unfortunately several conditions of the plan could not be fulfilled in proper sequence and the initial attempt failed. It is the purpose of this paper to discuss the initial operation of the digestion system and to describe the steps taken which ultimately led to successful operation after the initial failure.

Treatment Plant and Receiving Stream

The Alexandria sewage treatment plant is designed for an anticipated average dry weather flow of 18 m.g.d. The major treatment processes, after lift pumping of the sewage, consist of mechanical screening, grit removal, primary settling, high-rate trickling filtration with a portion of the filter effluent being recirculated to the primary settling tank influent, final settling, separate heated sludge digestion and digested sludge elutriation, conditioning, and mechanical dewatering. Humus sludge from the final tanks is pumped directly to the digestion system. Chlorine may be applied to the raw sewage flow, the primary effluent, the trickling filter effluent, the final effluent, or any combination thereof. Screenings may be shredded mechanically and returned to the flow, or hauled away for burial or incineration. Grit may be either ejected pneumatically to a fill area on the plant property or hauled away to other disposal. Scum from the primary tanks is pumped directly to the primary digester. Dewatered sludge cake is stockpiled on the plant property and is available to the general public for use as a soil conditioner.

The plant effluent is discharged into a tidal flat of large surface area which comprises the mouth of Hunting Creek near its junction with the Potomac River. At low tide about 90 per cent of the flat is exposed, and the meandering creek channel and the plant effluent channel, which subsequently join, are clearly evident. At high tide the flat is covered to an average depth of 2 to 3 ft. of water, and the creek flow and the plant effluent flow do not follow defined channels.

It is important, therefore, that a high-quality effluent be maintained to prevent distribution of settleable organic matter over the bottom of the flat. It is also essential that the by-

passing of raw sewage or the discharge of sludge from the digesters into the receiving stream be avoided.

Sludge Digestion Facilities

Digestion facilities consist of two 95-ft. diameter digesters with a side water depth of 28 ft. Each tank has a volumetric capacity of 225,000 cu. ft. or 1,700,000 gal. The primary digester is equipped with a fixed cover and three draft-tube mixers which in normal operation circulate the contents from the top to the bottom of the tank. The secondary digester is not equipped with internal mixing devices, but it does have a floating gas-holder cover.

In normal operation, raw sludge and scum from the primary settling tanks and humus from the final settling tanks are pumped through an external heat exchanger and into the top of the primary digester. Displaced partially digested sludge is transferred by gravity from the bottom of the primary digester to the middle elevation of the secondary digester through a transfer box located at the top of the primary digester. Completely digested sludge is withdrawn from the bottom of the secondary digester for elutriation, conditioning, and dewatering.

The contents of the primary digester are maintained at a temperature of 90° F. by constant recirculation from bottom to top through the heat exchanger. Heat is supplied by the jacket water from three gas engines which drive the main sewage lift pumps. Auxiliary heat can be provided from the plant steam heating system. The draft-tube mixers on this digester are operated continuously to provide good seeding of the raw solids input and to maintain uniform temperature within the digester.

The contents of the secondary digester are neither mixed by recirculation nor heated. Supernatant liquor is withdrawn through a selector and a gaging and sampling device. It is returned by gravity to the raw sewage flow at the plant inlet. The piping arrangement of the system will permit recirculation and heating of the secondary digester contents.

Gas generated in both digesters is collected under the floating gas-holder cover on the secondary digester and is distributed under the pressure provided by the cover to the points of utilization in the plant. The gas is used as fuel for the sewage lift pump engines and for the plant low pressure steam heating boilers. Excess gas is burned. Meters are provided for measuring the volume of gas produced, wasted, and used. Natural gas may also be used as an auxiliary fuel for both the engines and the boilers.

Initial Start-Up Plan

The author was acquainted personally with the digester start-up problems and experiences at the Little Miami Sewage Works as reported by Backmeyer (1). One of the major conclusions drawn from these experiences was that the input of raw solids to new digesters should be limited to about .01 lb. of volatile solids per cubic foot of digester capacity per day, or about one-tenth of the usual nominal design loading. Regulation of loading should be controlled by the volatile acids concentration in the digester, which should not exceed 1,800 p.p.m. To achieve this requires scheduled by-passing of raw sewage, which in the case of Alexandria was impracticable. The influence of tidal action on the receiving stream, the hot humid weather at the time of initial plant operation, and the proximity of the plant to residential areas made it necessary to avoid any practices that would produce odors.

The start-up plan adopted required the pumping of all accumulated fresh solids to the digestion system and permitted no by-passing for solids input control. The plan was as follows:

1. The primary digester would be filled with sewage to the overflow elevation.

2. The tank contents would be circulated through the heat exchanger to raise the temperature to 85° to 90° F. and the temperature was to be maintained at that level.

3. Initially 150 lb. of diammonium phosphate (commercial fertilizer grade) would be introduced to the digester.

4. About 30,000 gal. of well-digested seeding sludge would be added.

5. Primary sludge would be pumped to the digester and about 15 lb. per day of diammonium phosphate would be added.

6. The displaced mixture from the tank was to flow back to the plant inlet via the overflow drain.

7. The draft tube mixers would be operated continuously.

8. The pH would be maintained at 7.0 or more and the volatile acids at less than 1,800 p.p.m. The diammonium phosphate dosage would be increased if the pH dropped below 7.0 or the volatile acids exceeded 1,800 p.p.m.

This plan of operation was suggested by the consulting engineers for the Authority, based on experience with the digestion of packing house and cannery wastes. It was used successfully in starting the digesters at Knoxville, Tenn. The addition of diammonium phosphate was intended to provide nutrients for encouraging the growth of desirable organisms.

Starting Conditions

At the time sewage was first admitted to the plant on July 17, 1956, most of the major structures and equipment installations had been completed, but there were still many items of work to be finished. Filling of the primary digester with sewage was begun on the first day of operation and was continued over a period of five days. The sewage input was preheated through one section of the double-banked heat exchanger and the digester contents were recirculated continuously through the other section of the heat exchanger. The only available source of heat was the jacket water from the sewage pump engines. It was soon found that there was not sufficient heat from this source to raise the temperature of the digester contents above 75° F. Thus the optimum temperature of 85° to 90° F. could not be obtained.

A local septic tank maintenance firm was engaged to haul seed sludge from the neighboring Arlington County treatment plant for addition to the digester during the initial filling. Unfortunately wet weather during this period caused a delay in the planned introduction of seed sludge.

Withdrawal of raw sludge from the settling tanks was delayed in hope that the seed sludge could be added before fresh solids were introduced to the system. Raw sludge, however, soon accumulated in the settling tanks to a point where withdrawal was necessary before either of the two conditions could be met. On July 26 the first raw sludge was pumped to the digester. At this time the tank temperature was 75° F., the volatile acids concentration was 150 p.p.m., and the pH was 6.7. The required 150 lb. of diammonium phosphate also was added.

On July 31 and August 1, 30,000 gal. of digested sludge, having a total solids content of 9 per cent, a pH of 7.0, and a volatile acids concentration of 150 p.p.m., was added to the digester. A few days previously, the plant boilers had been placed in service on natural gas to provide additional heat and the tank temperature at the time of seeding was 85° F. The digester volatile acids concentration was 380 p.p.m. and the pH was 5.9 at the time of seeding.

Initial Progress

The progress of the digestion system during the first three months of operation is shown graphically in Figure 1. Only total and volatile solids, volatile acids, and pH determinations could be made because the laboratory facilities were incomplete. Of additional value

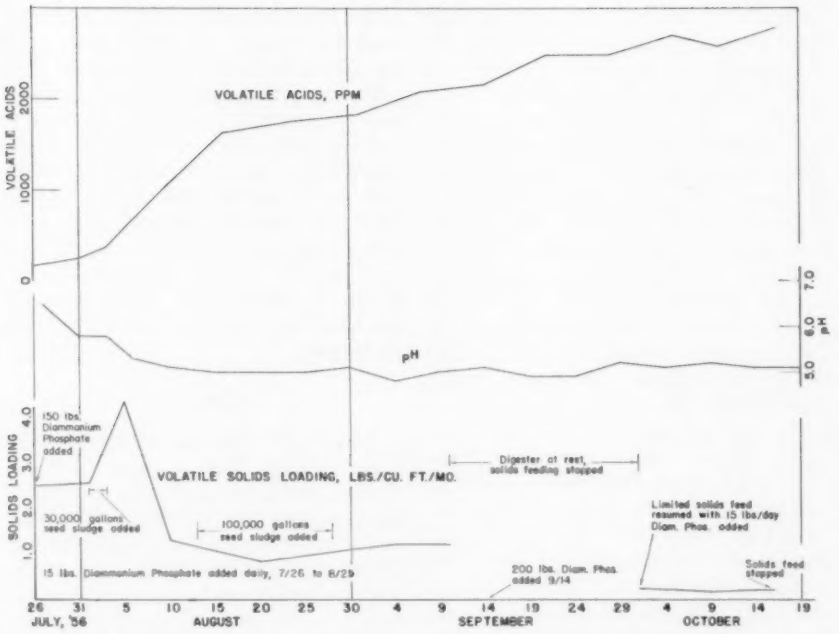


FIGURE 1.—Primary digester performance during initial start-up.

would have been a record of the gas volume and quality produced in the system; however, it was believed that impurities in the initial low quality gas would foul the gas meters.

During the first six weeks of operation no attempt was made to control the raw solids loading of the digester due to the inadvisability of by-passing raw sewage. Initial loadings resulting from a build-up of solids in the treatment plant and the interceptor system were quite high. During most of this period, the prescribed daily additions of 15 lb. of diammonium phosphate were made.

The volatile acids concentrations rose at a rapid rate (Figure 1) with a resultant drop in pH. This souring trend indicated that little, if any, results were being realized from the addition of diammonium phosphate. By August 9, the volatile acids had increased to 1,200 p.p.m. and the pH had dropped to 5.2. Volatile solids loadings at that time were about 1.5 lb. per cubic foot of digester capacity per month, or about five times that recommended by Backmeyer (1) for starting a new digester.

The rising volatile acids trend appeared to justify the reduction of solids loading through raw sewage by-passing regardless of the consequences. In an attempt to stop the increase in volatile acids, an additional 100,000 gal. of seed sludge was hauled in and pumped to the digester during the following two-week period. The only apparent effect of the new seed sludge was a slight decrease in the slope of the volatile acids curve. If the weather conditions at the time had permitted addition of the seed over a shorter period of time, more benefits might have been realized.

By September 9, the volatile acids had exceeded the 1,800 p.p.m. limit and the pH was hovering around 5.0. It appeared that a sour digester was in the making and the situation was

viewed with alarm. Natural gas bills were running approximately $700.00 per month and heating requirements were increasing with the advent of cool weather. Also, odors emanating from the digester gas, which was being vented to the atmosphere, were causing numerous complaints from nearby residents. It was then decided to rest the digester for a period of two or three weeks by diverting the raw sludge input to the secondary digester, which had heretofore been standing empty and unused. A "shock" load of 200 lb. of diammonium phosphate would be added to the primary digester.

Feeding of raw sludge to the primary digester was discontinued from September 10 to October 1. During this period, the temperature was maintained at 90° to 95° F. and the digester contents were kept mixed. The volatile acids leveled off at 2,500 p.p.m. and the pH rose one- or two-tenths of a point—hardly an improvement, but somewhat encouraging. At the end of the three-week rest period, a program of controlled solids feeding was commenced. Additions were limited to a rate of about 0.6 lb. of volatile solids per cubic foot per month, or 0.02 lb. of volatile solids per cubic foot per day. The feeding of 15 lb. of diammonium phosphate per day was also resumed. During the period of limited feeding, the pH remained at 5.2 and the volatile acids resumed their upward trend.

By the middle of October, the volatile acids had risen to 2,800 p.p.m., and it was apparent that the solids control measures were not effective in retarding acid formation. Fortunately there was ample capacity remaining in the secondary digester, and raw solids feeding to the primary tank was again discontinued on October 17. There was the hope that a longer rest period might result in recovery.

For nearly six weeks no solids were added to or withdrawn from the primary digester, and the addition of diammonium phosphate was discontinued. The tank contents, however, were kept mixed and heated and were sampled daily for laboratory analysis. The volatile acids increased to 3,000 p.p.m. and remained at that level and the pH held at 5.0. During this time, conditions in the secondary digester, which was receiving the full solids loading with no heating or mixing, were rapidly approaching the same state as those in the primary digester. In addition, a scum layer of appreciable thickness was forming under the floating cover.

Liming

Faced with the possibility that the digesters might have to be emptied and started again, the addition of lime as an expedient for overcoming the acid conditions was considered. Liming had been tried with no success by Backmeyer, but others had reported favorable results. Since re-starting the system would require an additional several weeks or possibly months before alkaline digestion, usable gas, and reduced odors could be obtained, preparations for liming were made.

The literature was searched in an effort to determine a rate of lime feeding which would most benefit the conditions existing in the system without producing foaming. Sawyer *et al.* (2) reported that the addition of lime in amounts totaling as much as 200 per cent of the volatile acids content of a digester, expressed as weight, produced favorable digestion conditions within 40 days without detrimental effects. On this basis, about 42 tons of lime would be required for the digester.

Feeding was begun at the rate of six bags per hour, or 3,600 lb. of hydrate per day. This rate would be decreased if favorable results were obtained.

On November 28, lime was pumped as a 1 lb. per gallon water slurry directly into a pipe line through which sludge was being recirculated from the bottom to the top of the digester. The equipment consisted of a mechanically

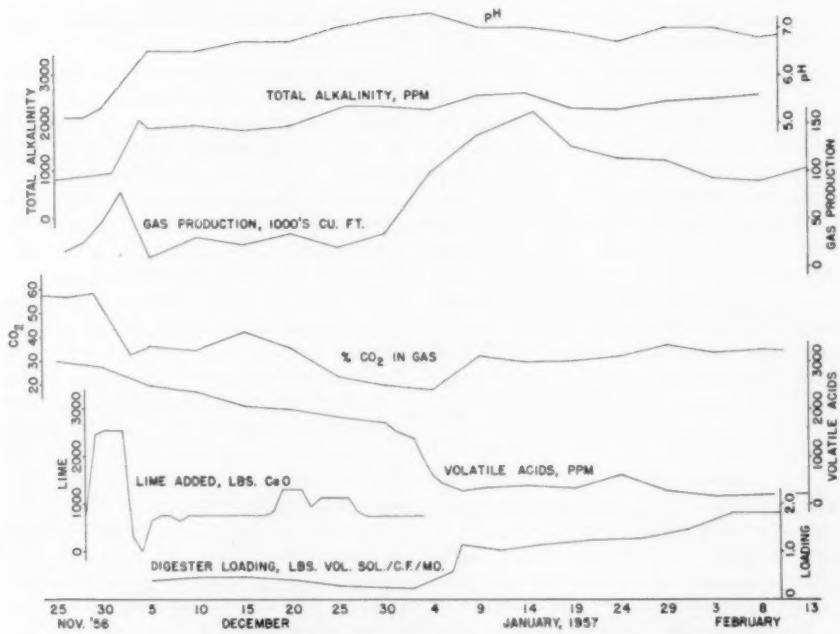


FIGURE 2.—Primary digester performance during and after the addition of lime.

agitated slurry tank and a variable speed diaphragm feed pump. The lime was purchased in the hydrated form in 50-lb. bags and contained an average of 75 per cent CaO by weight. Lime of poorer quality was available at less cost, but the volume of sand it contained might have caused trouble by deposition on the bottom of the digester.

Results of Liming

Figure 2 shows the almost spectacular results obtained within the first few days following the addition of lime. The first indication of increased digester activity was the gas production which multiplied five-fold within the first five days. Sharp improvements in gas quality, pH, and total alkalinity occurred almost overnight. Volatile acids, although slower to respond, began a downward trend.

After a week of liming at the relatively heavy rate of 3,600 lb. per day, the feed was reduced to about 1,000 lb. of hydrate or about 750 lb. of CaO per day, and the raw primary sludge from one shift was added per day. This operation was continued for a period of almost two weeks during which time the rate of improvement, although much less spectacular, was in a positive direction.

By the middle of December the tank contents had reached a somewhat static condition with the volatile acids at about 2,100 p.p.m., the pH at about 6.6, the total alkalinity at about 2,000 p.p.m., and the gas production between 20,000 and 25,000 cu. ft. per day. The lime feed was first doubled for a period of three days and then trimmed back to a rate of 1,800 lb. of hydrate, or 1,100 lb. of CaO, per day for five days. Additional improvement was noted. When the downward volatile acids trend was again evident, the lime feed was reduced to the previous rate of 1,000 lb. per day.

By January 3, 1957, the volatile acids concentration had decreased to

less than 1,000 p.p.m., the pH was 7.1, the total alkalinity had increased to 2,300 p.p.m., and the gas production and quality had improved. Accordingly, the addition of lime was discontinued and the raw solids feed was doubled by adding the primary sludge from two shifts per day instead of one. Conditions continued to improve (Figure 2) at a rapid rate, and beginning on January 7 all primary clarifier raw sludge and final humus were pumped to the primary digester. Good alkaline digestion had finally been established and lime feeding was no longer necessary.

Gas Production and Quality

The history of the gas production and quality during the digester start-up is worthy of separate mention. It was of prime importance that a sufficient quantity of usable gas be produced in the shortest possible time.

On October 25, 1956, the production and waste gas meters were placed in service and analysis of the carbon dioxide content of the gas was begun on a routine basis. It was found that the gas could be burned to waste, but only if large quantities under low pressure were available at the waste gas burner. Burning was a desirable method of disposing of the extremely odorous gas; therefore, the gas was stored under the floating gas-holder cover until sufficient quantity was available. By removing the weights from the pressure regulator, unrestricted flow of gas at low pressure was obtained at the waste gas burner. Since gas was then being produced in quantities of less than 1,000 cu. ft. per day, intermittent operation of the burner resulted.

Prior to the addition of lime to the system, gas was produced at the average rate of 12,000 cu. ft. per day, about 60 per cent of which was carbon dioxide. This is normally characteristic of a "pickled" digester. The initial heavy dosage of lime produced a short period of high-rate generation of relatively good quality gas, after which the production dropped abruptly and then began a slow steady increase.

During the liming period, the CO_2 content of the gas remained at a relatively low concentration and the flame at the waste burner was yellow and steady. The gas would burn under normal operating pressure in low quantities and the pilot would remain lit. Undoubtedly the lime was absorbing much of the CO_2 and H_2S from the gas. This became evident when the CO_2 concentration dropped to a subnormal low of less than 20 per cent during the first part of January, 1957.

In the middle of December, 1956, the gas was produced in sufficient quantity and quality to use for fuel in the heating system steam boilers. It was not until the middle of January, 1957, however, that the gas was considered to be of sufficient quality to burn in the pump engines. The conversion from natural gas was made with no subsequent difficulties.

Following the termination of lime addition, gas production rose to more than double the quantities normally expected from the current solids loading. This was undoubtedly due to the rapid digestion of the backlog of solids which had built up in the system since the beginning of operation. By the middle of February, 1957, gas production had decreased to normal quantities and the digester had settled down to normal operation.

Secondary Digester Conditions

A considerable quantity of raw solids had been pumped into the secondary digester during the resting and controlled solids feeding periods of the primary digester. Periodic spot checks of the contents showed that acid conditions prevailed. Also, a scum layer 2 to 3 ft. thick had formed and odors were emanating from around the periphery of the cover.

On January 7, 1957, the date that full loading of the primary digester was resumed, displaced sludge, which had previously been discharged to the

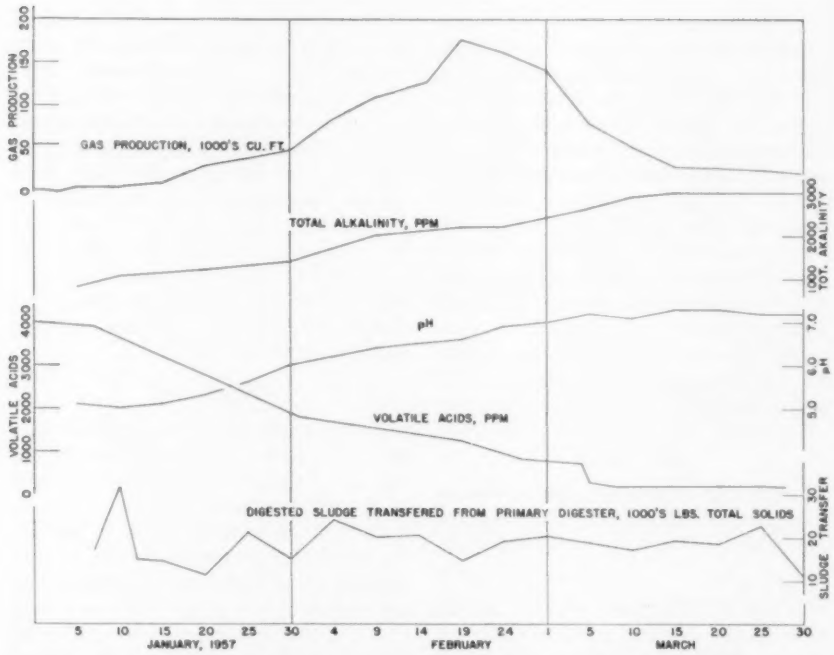


FIGURE 3.—Secondary digester performance, showing the seeding effects of the transfer of primary digester solids.

plant inlet, was allowed to transfer by gravity from the bottom of the primary digester to the middle elevation of the secondary digester. At this time the volatile acids concentration in the secondary digester was about 4,000 p.p.m. and the pH was 5.0.

Figure 3 shows the seeding effects in the secondary digester resulting from the sludge transferred from the primary tank. During January, the gas production increased from virtually nothing to almost 50,000 cu. ft. per day. Unfortunately, quality analyses of the secondary digester gas could not be made because gas from both digesters is collected under the floating cover on the secondary digester. Volatile acids during this period showed a decline from 4,000 p.p.m. to 1,800 p.p.m., and the pH rose from 5.0 to 6.3.

During the third week in February, the gas production increased to a maximum of 176,000 cu. ft. per day. Again, as in the primary digester, the rapid digestion of the solids backlog in the system was responsible for the abnormal production of gas. At this time some foaming was observed in the secondary digester, although it was not enough to present any operating problems. By the end of the month, the volatile acids had decreased to 800 p.p.m. and the pH had risen to 7.0. The scum layer on the surface of the digester had been destroyed by the action of the gas.

This surge of activity in the secondary digester, although indicating improved conditions, was not without its operating difficulties. Turbulence caused by the high rate of gas production resulted in mixing of the contents so that no clear supernatant stratum was obtained. Sludge conditioning and dewatering operations, which had been started earlier in the month, had to be geared to the volumetric input to

the digestion system without the benefit of supernatant return to the plant. Also, the sludge, although relatively well digested and free from objectionable odor, would continue to generate gas in the elutriation tanks. This resulted in poor settling and consolidation.

By the end of March, normal digestion had been established in the secondary tank. Volatile acids were less than 200 p.p.m., pH was at 7.2, total alkalinity was 3,000 p.p.m., the gas production was about 20,000 cu. ft. per day, and the supernatant stratum had been restored.

Summary

Failure to obtain the desired results from the initial digester start-up attempt can be attributed to the following:

1. Inability to carry out the conditions of the original start-up plan in proper sequence, *i.e.*, the pumping of raw solids to the digester before proper digester temperature could be reached and before the addition of seed sludge could be accomplished.
2. Lack of fresh solids control which resulted in the addition of solids to the system far in excess of that desirable for starting a new digester.

Rescue of the system from failure, and the ultimate establishment of normal digestion conditions can be credited to:

1. Extensive application of lime to provide proper alkaline conditions for the optimum growth of methane producing organisms.
2. Proper control of fresh solids input to the primary digester by diverting excess raw sludge to the secondary digester.
3. Extensive use of the volatile acids determination as a measure of control and regulation of lime addition.
4. Sufficient digester capacity which permitted an extended start-up period without overloading the facilities.

The total quantity of lime used amounted to approximately 27 tons, representing a cost of $540.00. This cost was more than offset through the resultant savings realized by being able to use the improved quality digester gas for fuel at an earlier date than would otherwise have been possible.

The conclusions reached by Sawyer *et al.* (2) were more than corroborated. Satisfactory digestion was established within 36 days following a total lime feed of only 120 per cent of the original volatile acids content.

Conclusions

1. Wherever possible, the fresh volatile solids feed to a new digester should be limited to approximately 10 per cent of the nominal design loading.
2. It is essential that a new digester be brought to optimum temperature (90° to 95° F.) before introduction of raw solids.
3. If practicable, addition of seed sludge should be accomplished before any raw sludge is introduced.
4. Digesters having a volatile acids condition of not more than 3,000 p.p.m. may respond to lime treatment. In a large-sized digester it may be possible to initially feed lime at a rate of 2,500 lb. of CaO per day without producing foaming. Lime should be of high quality with a minimum of sand and a maximum CaO content. For maximum effective results the lime should be fed as a slurry (1 lb. per gallon of water) into a pipe line through which the digester contents are being circulated, or into the top of a draft tube mixer.
5. Liming, if producing the desired results, should not be discontinued until the volatile acids have been materially reduced; *i.e.*, below 1,000 p.p.m. The rate of lime addition, however, can be decreased as digester conditions improve.
6. The value of the volatile acids determination as an effective control tool cannot be overemphasized. Creation of artificial environments through such practices as liming can cause rapid and

dramatic changes in such traditional parameters as total alkalinity, pH, gas production and quality. However, these do not necessarily reflect the day-by-day biological conditions in the system. Unless favorable readings of alkalinity, pH, etc., are accompanied by low volatile acids concentrations, they merely reflect a trend, and discontinuance of such practices as are responsible for these conditions without consideration of volatile acids may result in degradation of the digestion progress.

7. Digester gas containing as high as 60 per cent CO_2 by volume may burn in a waste gas burner if supplied to the burner in large quantities under low pressure (3 or 4 in. w.c.). Such gas will burn with a pale blue flame and be difficult to keep ignited without a pilot flame. Gas containing 45 per cent or less CO_2 will burn well at operating pressures (6 to 10 in. w.c.) in smaller quantities with no ignition problems and the flame will be yellow and voluminous. Gas of this quality can be used as fuel for boilers or furnaces, but should contain 35 per cent or less CO_2 for use in internal combustion engines.

8. Digester liming will produce a gas of unusually low CO_2 content. This, in itself, should not be taken as an indication of improved digester conditions as it is a result of the CO_2 combining with the lime to form calcium carbonate. Under these conditions, the CO_2 production could be high, but not show up in the gas analysis.

9. Even though high-rate digestion studies have shown that smaller digester capacities can be utilized in well-operating systems, ample digester space should be provided to permit a reasonable period of time for start-up at the beginning of operation and for recovery from adverse conditions that may be encountered from time to time during operation.

Acknowledgment

The suggestions and constructive criticism of James J. Corbalis, Jr., Engineer-Director, Alexandria Sanitation Authority, are greatly appreciated.

References

1. Backmeyer, D. P., "How to Avoid Sour Digesters." *Water and Sewage Works*, **102**, 369 (1955).
2. Sawyer, C. N., Howard, F. S., and Pershe, R., "Scientific Basis for Liming of Digesters." THIS JOURNAL, **26**, 8, 935 (Aug., 1954).

SEWAGE PUMP BEARINGS AND PACKING*

By Paul Ehrenfest

Havens and Emerson, Consulting Engineers, Cleveland, Ohio

In sewage treatment plants, the work horse among pumps is usually the single-stage centrifugal pump. The present design of the so-called "non-clog" pump is the result of many years of trial-and-error experimentation. Radical changes in design have, of course, taken place in the shift from steam to electricity. The older designs favored single-suction action, with impellers of large diameter and slow rotational speeds, because these pumps were steam driven. As electricity became more generally available and economical to use, it tended to replace steam as the prime mover for pumps because it offered more efficiency and faster rotational speeds. The old slow-speed, large-diameter impellers, with almost parallel shrouds to give ample clearance for water passages, were replaced. Their low pumping efficiencies and low exit velocities at the discharge were no longer economical. But, though pumping efficiency generally

* Presented at the 1957 Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conf.; Dayton, Ohio; June 19–21, 1957.

the digestion system without the benefit of supernatant return to the plant. Also, the sludge, although relatively well digested and free from objectionable odor, would continue to generate gas in the elutriation tanks. This resulted in poor settling and consolidation.

By the end of March, normal digestion had been established in the secondary tank. Volatile acids were less than 200 p.p.m., pH was at 7.2, total alkalinity was 3,000 p.p.m., the gas production was about 20,000 cu. ft. per day, and the supernatant stratum had been restored.

Summary

Failure to obtain the desired results from the initial digester start-up attempt can be attributed to the following:

1. Inability to carry out the conditions of the original start-up plan in proper sequence, *i.e.*, the pumping of raw solids to the digester before proper digester temperature could be reached and before the addition of seed sludge could be accomplished.
2. Lack of fresh solids control which resulted in the addition of solids to the system far in excess of that desirable for starting a new digester.

Rescue of the system from failure, and the ultimate establishment of normal digestion conditions can be credited to:

1. Extensive application of lime to provide proper alkaline conditions for the optimum growth of methane producing organisms.
2. Proper control of fresh solids input to the primary digester by diverting excess raw sludge to the secondary digester.
3. Extensive use of the volatile acids determination as a measure of control and regulation of lime addition.
4. Sufficient digester capacity which permitted an extended start-up period without overloading the facilities.

The total quantity of lime used amounted to approximately 27 tons, representing a cost of $540.00. This cost was more than offset through the resultant savings realized by being able to use the improved quality digester gas for fuel at an earlier date than would otherwise have been possible.

The conclusions reached by Sawyer *et al.* (2) were more than corroborated. Satisfactory digestion was established within 36 days following a total lime feed of only 120 per cent of the original volatile acids content.

Conclusions

1. Wherever possible, the fresh volatile solids feed to a new digester should be limited to approximately 10 per cent of the nominal design loading.
2. It is essential that a new digester be brought to optimum temperature (90° to 95° F.) before introduction of raw solids.
3. If practicable, addition of seed sludge should be accomplished before any raw sludge is introduced.
4. Digesters having a volatile acids condition of not more than 3,000 p.p.m. may respond to lime treatment. In a large-sized digester it may be possible to initially feed lime at a rate of 2,500 lb. of CaO per day without producing foaming. Lime should be of high quality with a minimum of sand and a maximum CaO content. For maximum effective results the lime should be fed as a slurry (1 lb. per gallon of water) into a pipe line through which the digester contents are being circulated, or into the top of a draft tube mixer.
5. Liming, if producing the desired results, should not be discontinued until the volatile acids have been materially reduced; *i.e.*, below 1,000 p.p.m. The rate of lime addition, however, can be decreased as digester conditions improve.
6. The value of the volatile acids determination as an effective control tool cannot be overemphasized. Creation of artificial environments through such practices as liming can cause rapid and

dramatic changes in such traditional parameters as total alkalinity, pH, gas production and quality. However, these do not necessarily reflect the day-by-day biological conditions in the system. Unless favorable readings of alkalinity, pH, etc., are accompanied by low volatile acids concentrations, they merely reflect a trend, and discontinuance of such practices as are responsible for these conditions without consideration of volatile acids may result in degradation of the digestion progress.

7. Digester gas containing as high as 60 per cent CO_2 by volume may burn in a waste gas burner if supplied to the burner in large quantities under low pressure (3 or 4 in. w.c.). Such gas will burn with a pale blue flame and be difficult to keep ignited without a pilot flame. Gas containing 45 per cent or less CO_2 will burn well at operating pressures (6 to 10 in. w.c.) in smaller quantities with no ignition problems and the flame will be yellow and voluminous. Gas of this quality can be used as fuel for boilers or furnaces, but should contain 35 per cent or less CO_2 for use in internal combustion engines.

8. Digester liming will produce a gas of unusually low CO_2 content. This, in itself, should not be taken as an indication of improved digester conditions as it is a result of the CO_2 combining with the lime to form calcium carbonate. Under these conditions, the CO_2 production could be high, but not show up in the gas analysis.

9. Even though high-rate digestion studies have shown that smaller digester capacities can be utilized in well-operating systems, ample digester space should be provided to permit a reasonable period of time for start-up at the beginning of operation and for recovery from adverse conditions that may be encountered from time to time during operation.

Acknowledgment

The suggestions and constructive criticism of James J. Corbalis, Jr., Engineer-Director, Alexandria Sanitation Authority, are greatly appreciated.

References

1. Backmeyer, D. P., "How to Avoid Sour Digesters." *Water and Sewage Works*, **102**, 369 (1955).
2. Sawyer, C. N., Howard, F. S., and Pershe, R., "Scientific Basis for Liming of Digesters." THIS JOURNAL, **26**, 8, 935 (Aug., 1954).

SEWAGE PUMP BEARINGS AND PACKING*

BY PAUL EHRENFEST

Havens and Emerson, Consulting Engineers, Cleveland, Ohio

In sewage treatment plants, the work horse among pumps is usually the single-stage centrifugal pump. The present design of the so-called "non-clog" pump is the result of many years of trial-and-error experimentation. Radical changes in design have, of course, taken place in the shift from steam to electricity. The older designs favored single-suction action, with impellers of large diameter and slow rotational speeds, because these pumps were steam driven. As electricity became more generally available and economical to use, it tended to replace steam as the prime mover for pumps because it offered more efficiency and faster rotational speeds. The old slow-speed, large-diameter impellers, with almost parallel shrouds to give ample clearance for water passages, were replaced. Their low pumping efficiencies and low exit velocities at the discharge were no longer economical. But, though pumping efficiency generally

* Presented at the 1957 Annual Meeting, Ohio Sewage and Industrial Wastes Treatment Conf.; Dayton, Ohio; June 19–21, 1957.

increased, the increased impeller rotation, tapering of shrouds, and smaller clearances also increased the problem of clogging.

Pump Development

Clogging

An obvious solution to the problem of clogging was to use a double-suction pump. One apparent advantage of this type of pump was the ease with which lubricating and cooling water could be gotten to the seal cage, as tappings could easily be drilled into the upper casing. However, disadvantages were numerous and serious. The area through the impeller passages was only half that of a single-suction pump of the same capacity. The revolving pump shaft and the sleeve passing through the inlet parts to the eye of the impeller allowed stringy material to become entangled and wrapped around the shaft. This soon clogged the pump.

Modern Design

Pump manufacturers gradually developed a special impeller with the casing redesigned to handle solids and stringy materials efficiently. This design led to the development of the single-suction centrifugal pump which gives a smoother and more even flow and a linear relationship between head capacity and power consumption. The torque required for starting is small and, in general, the operating load is fairly smooth and free from shock. Such pumps are generally termed "non-clog." However, this is a relative term since the "sphere size" of the pump denotes the largest diameter ball which can pass through the pump; not necessarily through the connected piping, suction or discharge. This type of pump usually provides relatively large cross-sectional areas for liquid flow, and smooth and gradual contours for all curved surfaces. Shaft sleeves, usually of stainless steel or monel, are corrosion-resistant as well as wear-resistant. Adequate inspection openings should be cast into the pump or provided in adjacent piping to facilitate cleaning of the impeller. Stuffing boxes for this purpose are most often water-sealed and lubricated with grit-free clean water. Care must, of course, be taken to see that there is no interconnection between the gland and a potable water supply. Because of excessive grit encountered in sewage service pumping, mechanical and grease seals are not in general use for this purpose.

Bearings

Single-suction horizontal centrifugal pumps usually have over-hung impellers with no internal bearings. This requires the use of rather large shaft diameters to take care of the bending moment or force due to the distance from the impeller eye and the external bearing. There is also a hydraulic unbalance, not found in a double-suction pump, which requires the shaft to transfer thrust loads to the external bearings. This load consists of the difference between the discharge and the suction pressure which is applied to the eye of the impeller. Mechanically these forces can be resolved readily and handled through anti-friction roller bearings rigidly supported on the pump base. In some cases sleeve bearings may be used in combination with adjustable thrust bearings.

In general, the maintenance and lubrication of any type of bearing will present no problem if the manufacturer's recommendations are followed with respect to the grade and type of lubricant used. A reputable pump manufacturer assumes responsibility for the selection of bearing design which is adequate, with respect to loads, bearing supports, etc., for the job the pump is expected to perform—just as he assumes responsibility for the machining of shafts and housings and the general assembly of the various components.

Pump Performance

The life history of a pump at the job site depends upon many factors.

Good performance is the joint responsibility of the pump manufacturer, the engineer who recommended the specific pump for the particular job, the contractor who installed it and, above all, on those who operate and service it. The responsibilities of the manufacturer are beyond the scope of this paper, as are the theoretical reasons governing the selection of a specific pump. The latter may be considered as academic in the sense that the proper application of engineering and hydraulics principles will set a definite parameter which may be used as a basis for determining the piece of equipment which will fulfill the engineering and hydraulic requirements of the job in the most efficient and economical manner.

There are many ills and chronic diseases that may affect a pump. The care which the pump and motor receive during storage at the job site, during installation, after installation, and in the service for which it was chosen are all important factors in determining whether a pump gives satisfactory or unsatisfactory service. The following are some of the preventive measures that can help in reducing the "down time" of pumps.

Pump Installation and Maintenance

The importance of the personal element in good installation and maintenance are self-evident. It is statistically possible for the pump manufacturer to turn out "a real lemon," but it must be conceded that this is a very rare occurrence. The pump in question is usually the most efficient and "best buy" for the job. It deserves good care, prompt attention when repairs are needed, and, above all, a human respect for a good piece of machinery.

Installation Precautions

During the installation of a pump, there are many factors which may disturb alignment of the shaft. If this occurs, the bearings and seal cage bushing may be affected, causing excessive leakage from the seal cage. Pump foundations should be substantial to give full support to the pump base plate. The base plate should be carefully leveled before grouting. Any movement of the foundation, due to foundation settling, will disturb alignment. Piping should not be strained in order to make tight connections to the pump. The pump casing offers a poor support for a heavy cast iron pipe header. Both suction and discharge piping should be independently supported away from the pump foundation but they should be close enough so that, when flange bolts are tightened, no strain will be transmitted to the pump casing. The pump casing should be checked to make sure that it is free from external strain, by removing the flange bolts before the pump is given final alignment for its initial trial.

Lubrication

During operation of the pump the importance of proper lubrication cannot be over-emphasized. It is usual for the manufacturer of the pump to give to someone connected with the sewage treatment plant, either in the initial stages of construction or the final stages of testing, his recommendations for the proper lubrication and maintenance of his product. These include instructions as to the grade of oil and grease to be used and the recommended frequency of use. These should be followed; bearings heat up just as often when too much grease has been used as when too little has been used. The nature of sewage and sludge is to include an ample supply of grit, sand, and other abrasive materials. These foreign solids are always present during operation and extreme care should be taken to avoid adding more of them in the grease and oil required for regular maintenance.

Pump Packing

Purpose of Packing

The cost of pump packing is a very minor part of the actual pump installa-

tion cost in comparison to such expensive items as pump controls and starters. All the packing must do is to seal the pump casing and prevent leakage from the interior of the casing. Yet negligence with respect to this small and relatively low-cost item can result in a major expense and can materially add to the pump down time. The seal-cage bushing, seal cage, and gland are designed by the manufacturer to withstand the full discharge pressure of the pump plus the hydrostatic head of the sealing water, which is approximately 5 to 10 p.s.i. higher than the discharge pressure of the pump. In order to make this assembly tight, packing is inserted between the bushing and the gland with a lantern ring to distribute the sealing water. The dual purpose of the lantern ring is to prevent abrasive material in the sewage from entering the seal cage and to lubricate and cool the seal between the shaft sleeve and the packing. Thus the shaft sleeve is protected, theoretically, from excessive wear.

When and How to Pack

The pump in the "as received" condition at the job site has, in the majority of cases, had the gland packed by the pump manufacturer. In many instances this means the packing has not been wetted for a year or more with the result that deterioration, due to drying, may have developed. It might be desirable to repack all pumps before initial service purely as a preventative measure. If the glands are not packed when received, packing should be done just prior to the initial operation of the pump. The gland and shaft sleeve should be carefully lined up, cleaned and flushed out before being packed. Packing should be supplied by the manufacturer of the pump and installed according to his recommendations. Caution should be exercised in placing the packing to be sure that sufficient packing is placed back of the lantern gland or seal cage to insure proper alignment between the sealing-water inlet and the seal cage. It should be remembered that, when the gland is pulled up, the packing will be compressed and the seal cage will move. In placing packing rings in the gland, care should be taken to cut each ring accurately to the proper length; cut ends should meet, not overlap. Each ring should be rotated a few degrees when inserted so that the joints do not overlap but are staggered. Each packing ring should be pressed into position, not driven or forced. The gland should be pulled up evenly with a wrench until it is moderately tight, backed off, and then tightened with the fingers. This allows the small amount of leakage which is required for every gland seal in order to prevent excessive heat. Too tight a gland causes excessive wear to the shaft sleeve plus an increase in power consumption. Leakage is needed for lubrication of the surfaces.

Packing is a small item but an important one. Most operators have a favorite brand of packing which they tend to prefer over the brand furnished with the pump. But the manufacturer of the pump has carefully noted the physical and chemical characteristics of the various types of packing available and the uses to which each type is suitable. In the long run it is more economical to be guided by his experience and advice than to depend on an unsupported preference. It is most important that the proper choice of packing material be made with reference to type of service required and special conditions which may be present.

Pump Condition

Another cause of packing difficulties may be the physical condition of the pump, and its related parts, with respect to past maintenance and the care which was exercised by the contractor in the initial installation. All mechanical equipment wears during ordinary usage. But misuse, improper mainte-

nance, and poor installation naturally accelerate wear and cause greater power consumption. Excessive packing troubles may be caused by roughness of the shaft sleeves. Misalignment of the shaft in the gland bushing and gland, with the shaft not being concentric due to unbalance and vibration of the impeller, will cause excessive leaking of the packing. This cannot be detected by manually rotating the pumps; shaft alignment must be checked with a dial indicator. As a general rule of thumb, the pump shaft should run true within .002 in. if packing troubles are to be avoided. Even if a flexible coupling is used between the motor and the pump, there is no need to neglect the proper and correct alignment of the shaft of the pump and of the drives. Checking the bed plate, upon which the pump and motor are mounted, is important. In time this base can warp because of movement in the foundation and improper and uneven pulling down of the foundation bolts during construction.

Conclusions

The principal guide in packing maintenance is to remember that a dry stuffing box is an invitation to trouble. Sealing water should be piped to the gland seals from a source that is clean, free from dirt and grit, and at a pressure of 5 to 10 p.s.i. greater than the maximum discharge head of the pump. The quantity of sealing water per gland is variable, depending on the manufacture of the pump and the degree of wear of the packing. Good design would include a throttling valve to regulate quantity of flow and a solenoid valve, interconnected to the motor starter, to prevent wasting of water when the pump is not in use.

Sealing-water systems are manufactured by many of the pump manufacturers. An economical system can easily be made from an ordinary package-style, farm-water system. Needless to say, all precautions should be taken to assure that the sewage system is not directly connected to a potable water system.

To keep a pump pumping and trouble-free, the pump must be carefully handled, installed, and maintained. The information furnished in the pump manufacturer's instruction book is based upon considerable experience in the operation and maintenance of thousands of pumps. Time spent in reading this book is never wasted.

PROPER PUMP MAINTENANCE*

Careful use of equipment will prolong its life and value. Following the manufacturer's instructions on lubrication, preventive maintenance, and use should provide many years of satisfactory operation.

Pumps will give the best service when a preventive maintenance schedule is followed. Actually, operating conditions vary so widely that to recommend only one schedule of preventive maintenance is highly impractical. The following items apply to the most severe applications, and can be modified as necessary.

Annually

Remove rotating element and inspect thoroughly for wear—ordering replacement parts if necessary. Check the clearances of the wearing rings; generally they should be no more than .003 in. per inch of diameter of wearing ring.

Remove any deposit or scaling. Clean out water seal piping. Measure total suction and discharge lifts as test of pipe conditions (record these data so they may be compared wtih those of next test).

Inspect foot valves and check valves

* *Yeomans Guard*, **14**, 2, 6 (June, 1957).

—especially valves which must safeguard against water hammer.

Semi-Annually

Replace packing, using the type recommended by the pump manufacturer. Make sure seal cages are centered in stuffing boxes at the entrance of water seal piping. Check shaft sleeves for scoring that would accelerate packing wear—order new sleeves if needed.

Check alignment of pump and motor, and shim up units as needed. Check entire piping system if misalignment recurs frequently. Unbolt piping at suction and discharge nozzles to see if it springs away—indicating strain on casing. Check all piping supports for soundness and effective support of load.

Quarterly

Drain lubricant, wash out oil wells and bearings with kerosene. In the case of sleeve bearings, check to see that oil rings are free to turn with the shaft. Repair or replace if defective. Refill with proper lubricant recommended by the pump manufacturer.

Measure bearings for wear, replace if excessive. Generally allow .002 of an inch clearance, plus .001 of an inch for each inch or fraction of an inch of shaft journal diameter.

Monthly

Check bearing temperature with thermometer—not by hand. If antifriction bearings are running hot, they probably have too much lubricant. If sleeve bearings are running too hot, they may need more lubricant. Disassemble and inspect bearings if change in lubrication doesn't correct condition. Check the alignment of pump and motor.

Maintenance Rules

1. If there is any danger that foreign matter (sticks, refuse, etc.) may be sucked into the pump—clogging or wearing the impeller unduly—provide the intake end of the suction piping with a suitable screen.

2. Never pump a liquid for which the pump was not designed.

3. Keep the right amount of the right lubricant in bearings at all times. Follow the pump manufacturer's lubrication instructions carefully.

4. See that pump and motor coupling flanges are parallel vertically and axially—and that they are kept that way.

5. Correct any down sloping toward the pump of the suction piping. This could reduce capacity and cause vibration.

6. See that piping puts absolutely no strain on the pump casing.

7. Never allow a pump to run dry (either through lack of proper priming when starting or through loss of suction when operating). Water acts as a lubricant between rings and impeller.

8. Examine wearing rings at regular intervals. When seriously worn their replacement will greatly improve pump efficiency. Some pumps have adjustments and these should be made when necessary.

9. Packing should be replaced periodically (depending on conditions), using the packing recommended by the manufacturer. Forcing in a ring or two of new packing instead of replacing worn packing is bad practice. It is apt to displace the seal cage and score shaft or shaft sleeve, as well as require more power.

10. Never tighten a gland more than necessary. Excessive pressure will wear shaft sleeves unduly and use extra power.

11. If shaft sleeves are scored badly, replace them immediately—or packing life will be entirely too short.

12. If the liquid being pumped contains grit, a separate source of sealing liquid should be obtained (it may be possible to direct some of the pumped liquid into a container and settle out the grit).

TIPS AND QUIPS

Pleasant Seat

In Prince Georges County, Md., the county government backs basic sanitation by building and selling privies for $100.00—$20.00 down and $10.00 monthly, installed, thereby holding the price line on privies, even in these inflationary days. Now, the county plans to move its privy plant to Forestville, Md.

When the county went into the privy business, some unknown and unsung administrative genius decided it would be an asset to establish the factory at its present site in Seat Pleasant, Md. Whoever he was, his beautiful sense of verbal harmony should not now be undone.

When privies are made in a place called Seat Pleasant, why change?

Autoclaved Pipe

Autoclaving asbestos-cement pipe reportedly slashes the curing time from three weeks to one day. The Keasbey & Mattison Company, Ambler, Pa., has ordered three 105-ft. autoclaves for the steam curing of asbestos-cement pipe manufactured by the company. Formerly, the pipe was cured under water for one week and then air cured for an additional two weeks before shipping.

Auxiliaries

It isn't only the eyes of Texas but those of the North Dakota Water and Sewage Works Conference that are turned on the ladies. Although we haven't received any communications from the North Dakota ladies (or any other lady or ladies) we read in the July–August, 1957 *Official Bulletin* of the North Dakota Water and Sewage Works Conference that the Auxiliary of the Conference is planning its first anniversary meeting at the 1957 meeting at Fargo, September 25–27.

President of the Conference Auxiliary and Chairman of the Local Arrangements Committee is Mrs. Harold H. Behlmer. The registration fee of $1.00 covers the ladies' activities, including luncheon (leave it to the ladies to manage the money).

We are pleased to learn of auxiliary activities, especially since our editorial earlier this year (THIS JOURNAL, **29**, 1, 88; Jan., 1957). However, it is not like the ladies to keep quiet about their plans or activities; correspondence would be welcome. Until then, "more power to the ladies."

Plastic Steel

An emergency repair kit recently made available contains Plastic Steel for on-the-spot repairs of tanks, pipes, pumps, valves and other types of machinery.

Plastic Steel is described as a compound of 80 per cent steel and 20 per cent plastic that can be handled as modeling clay and formed into any shape; it will not sag. The application of a special hardening agent, furnished with the repair kit, causes the compound to become a strong, tough, rigid metallic piece within 2 hr. The hardened material reportedly is essentially non-shrinking and non-expanding, and will not rust. It will harden under water. The use of heat (within prescribed limits) hastens the hardening process so that quick repairs can be made to service lines.

Reported to have great strength (resistant to internal pressures of 2,000 p.s.i.), the material can be used with glass tape to produce very strong repairs on pipe lines, pumps, tanks, etc.

Descriptive information is available from industrial dealers or from Devcon Corporation, 1220 Endicott St., Danvers, Mass.

Laboratory Safety Manual

The newest edition of the Fisher "Manual of Laboratory Safety" is a compact pocket-size volume which covers accident prevention, first aid, fire prevention, and safety equipment, and concludes with a safety bibliography. The material in the manual is grouped under the following sections:

How to Prevent Accidents in the Laboratory.
Laboratory First Aid and Fire Fighting.
Safety Equipment Available for Use in Laboratories.
Some Informative References on Laboratory Safety.

Copies of the manual may be obtained from Fisher Scientific Company, 717 Forbes St., Pittsburgh 19, Pa.

Plastic Pipe

The National Science Foundation has allowed its seal of approval to be placed on plastic pipe.

Floatless Parshall Flume Recorder*

The use of a differential pressure-cell transmitter will permit greater flexibility in the location of Parshall flume recording equipment. The cell transmitter senses back pressure in a bubble tube inserted in the floatwell; the output of the transmitter, a 3 to 15 p.s.i. air signal proportional to the well level, is received by a pneumatic receiver-recorder. A special chart which incorporates the exponents of the flow equation enables direct reading of flow.

The instrumentation eliminates conventional float-and-cable devices and associated maintenance problems, such as stretched and corroded cables and grease accumulation on floats.

* The Foxboro Company, Foxboro, Mass.

Sewer Gas Again!

Sewers may appear to be not only inelegent, mundane necessities of urban communities, but they can also be death dealing tombs waiting for the unwary, the uninformed, and the just plain stupid person who seeks to enter without applying the rudiments of safety.

Again we read of sewer personnel being either overcome by toxic gases or suffocated due to lack of oxygen. A person that enters a manhole without a safety rope and oxygen mask, and without proper ventilation of the sewer line, is asking for what all too frequently is the inevitable—death.

We were particularly concerned with the most recent newspaper account to come to our attention to read that two of the rescuing squad members attempted entry into the manhole—one without a mask and the other with a filter-type mask. It was not until an oxygen mask was used that the rescue was completed. How many precious minutes of life were ebbing away while faulty techniques were being tried will never be known—for fortunately the initial victim recovered and there were no fatalities among the would-be rescuers.

Truly the motto ". . . the life you save may be your own" is never more applicable than when applied to sewer maintenance work.

Consulting Engineers: Whitman and Howard — Photo—Dorr-Oliver, Inc.

VAREC SEWAGE EQUIPMENT

helps BURLINGTON, VERMONT keep LAKE CHAMPLAIN clean

"Varec"
SEWAGE EQUIPMENT

- Pressure Relief and Vacuum Breaker Valve
- Flame Arresters
- Flame Trap Assembly
- Explosion Relief Valves
- Waste Gas Burners
- Flame Checks
- Pressure Relief and Flame Trap Assembly
- Pressure Reducing Regulator
- Check Valves
- Drip Traps
- Sediment Traps
- Manometers

Burlington, Vermont, has installed the first modern sewage plant in Vermont to protect the waters of Lake Champlain for swimming, fishing and boating.

On the Dorr Multidigestion System, VAREC SEWAGE GAS CONTROL and SAFETY DEVICES protect the plant against fire and explosion, and regulate the volatile sewage gas for smooth operation.

With thousands of communities in the United States and Canada installing Varec Sewage Equipment, it is practically standard for controlling gases from sewage digesters. Send for VAREC Catalog S-3.

THE VAPOR RECOVERY SYSTEMS CO.
COMPTON, CALIFORNIA

Cable Address: VAREC COMPTON CALIFORNIA (U.S.A.)
All Codes

Available from Authorized Sewage Equipment agents throughout U. S. and Canada.

S-13

Proceedings of Member Associations

MICHIGAN SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

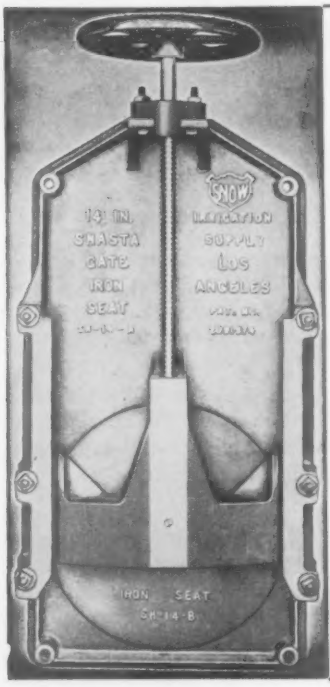
The Michigan Sewage and Industrial Wastes Association held its 32nd Annual Conference at the Park Place Hotel, Traverse City, Mich., on May 20–22, 1957. There was a total registration of 285 persons.

All of the technical sessions were of sufficient general interest to justify joint meetings in the technical sessions. Harold Titus, Conservation Editor for *Field and Stream,* keynoted the Conference with an address entitled, "An Outdoor Writer Looks at Water Conservation and Pollution Control." The first day's session also included a paper on "The Effect of Treated Effluent on Receiving Waters," by Jack Borchardt, Professor of Sanitary Engineering, University of Michigan, Ann Arbor.

A panel discussion on control of industry's use of municipal sewers was moderated by H. P. Dodge, Sanitary Engineer, Francis Engineering Co. Participating were: Robert Fryer, Assistant Director of the Michigan Municipal League; Floyd Vermette, Warren; and Donald Swets, Kalamazoo.

A second panel discussion, moderated by N. G. Damcose, Traverse City, dealt with the subject of manning sewage and industrial waste treatment plants with competent personnel. Participating were: Reginald Aikin, Caro State Hospital; Allan Kronbach, Mid-

(*Continued on page 444a*)



SNOW GATES
for
SEWAGE TREATMENT PLANTS

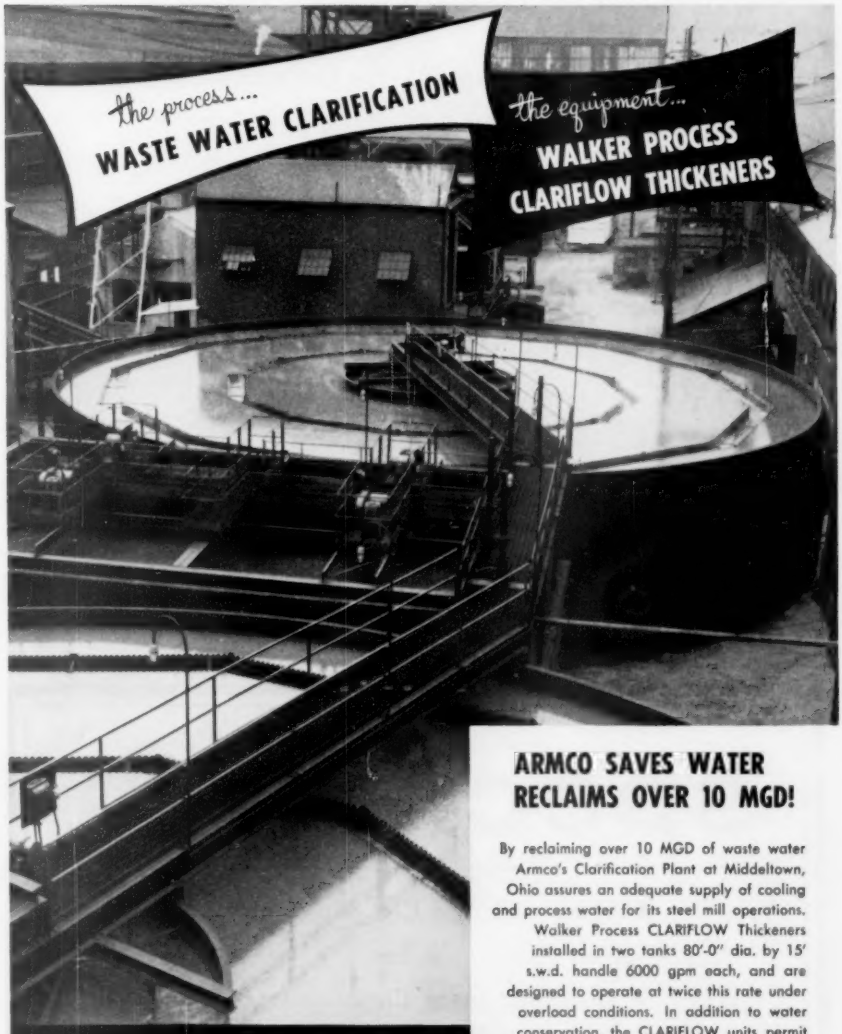
All types of cast iron gates manufactured in either square or circular opening in sizes up to and including 72 inches.

ALL SNOW GATES and Lifts are "Parkerized" for protection against rust and corrosion.

Over 40 years continuous service to the industry.

We will be pleased to quote on any type of water controlling equipment.

SNOW GATES & VALVES
2437 East 24th Street Los Angeles 54, Calif.



Armco's compact and efficient clarification plant, with chemical mixing at left followed by flocculation and finally clarification. Equipped by Walker Process with Rapid-Mix unit, four vertical F. S. flocculation units and two CLARIFLOW Thickeners.

ARMCO SAVES WATER RECLAIMS OVER 10 MGD!

By reclaiming over 10 MGD of waste water Armco's Clarification Plant at Middeltown, Ohio assures an adequate supply of cooling and process water for its steel mill operations. Walker Process CLARIFLOW Thickeners installed in two tanks 80'-0" dia. by 15' s.w.d. handle 6000 gpm each, and are designed to operate at twice this rate under overload conditions. In addition to water conservation, the CLARIFLOW units permit reclamation of approximately 20-40 tons per day of iron rich scale.

Engineering and manufacturing knowledge, plus experience gained on a variety of industrial waste treatment problems is offered to help solve your next project. Write for literature.

WALKER PROCESS

WALKER PROCESS EQUIPMENT Inc.
FACTORY • ENGINEERING OFFICES
LABORATORIES
AURORA, ILLINOIS

land; and Stanley Mogelnicki, Dow Chemical Co.

Other papers were presented on plant operations, control and treatment of industrial oils, health hazards to sewage and industrial waste treatment personnel, and control of radioactive wastes.

The Awards Committee reported that the nominee for the 1958 Bedell Award is Robert A. Greene. J. C. Marshall was nominated as candidate for the Hatfield Award.

The following officers were elected or continued in office:

President: Sam Porter, Ann Arbor.
First Vice-President: John Toomey, Birmingham.
Second Vice-President: Edward Fuess, Sturgis.
Secretary-Treasurer: D. M. Pierce, Lansing.

D. M. PIERCE,
Secretary-Treasurer

OHIO SEWAGE AND INDUSTRIAL WASTES TREATMENT CONFERENCE

The 31st Annual Meeting of the Ohio Sewage and Industrial Wastes Treatment Conference was held at the Miami Hotel, Dayton, Ohio, on June 19–21, 1957. Registration for the technical program totaled 244 members and guests. In addition, 48 ladies were in attendance.

The technical program was presented as concurrent sanitary and industrial wastes sessions. On the last day a general session was held, and the afternoon was given over to inspection trips.

Featured were two interesting panels: one on fringe-area sanitation and the other on the efforts by the paper industry to abate stream pollution in Ohio.

(*Continued on page 446a*)

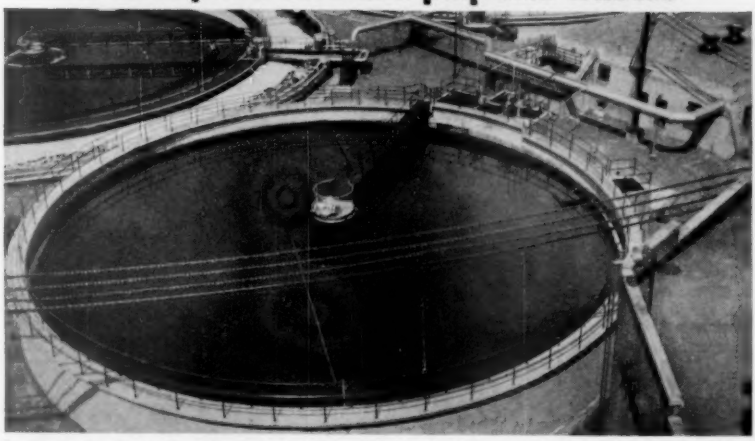
specialists

★ Sewer and Pipe Cleaning Equipment
★ Sewer Rods ★ Sectional Steel Rods
★ Complete Sewer Cleaning Machines
★ Braces and Guides
★ Buckets, Root Cutters, Drag Tools

Save the cost of experimenting. Consult Stewart for any problem in the specialized field of pipe cleaning.

W.H.STEWART, INC. P.O. Box 767, Syracuse, N.Y.

Rodney Hunt gates of tough Everdur withstand bleach-plant acid and pulp-mill wastes



Settling tanks of one of the first industrial waste-treatment plants in the paper industry at the Covington, Va., plant of West Virginia Pulp and Paper Co. Everdur was specified for mixing-chamber gates to resist corrosion by bleach-plant acids and pulp-mill wastes.

One of a pair of mixing-chamber gates fabricated of Everdur, each 48″ wide by 54″ high. The slide is a sheet of Everdur, reinforced by Everdur angles braze-welded in place. Frame and 2″ stem also of Everdur.

Resists corrosion. Sewage treatment and waterworks equipment of Everdur* has been in service without replacement for 20 years and longer.

Toughness. Everdur also possesses high strength and resistance to wear and abrasion —so that engineers can use lighter weight wrought material in their designs.

Readily fabricated. Alloys of Everdur are available for hot or cold working, welding, free machining, forging and casting — and can be obtained in plates, sheets, rods, bars, angles, channels, tees, I-beams, wire, tubes, electrical conduit and casting ingots.

Write for Publication E-11, "Everdur Copper-Silicon Alloys for Sewage Treatment and Waterworks Equipment" — or for technical help in selecting the correct material for your job. Address: The American Brass Company, Waterbury 20, Conn. In Canada: Anaconda American Brass Limited, New Toronto, Ont.

*Reg. U. S. Pat. Off. 57131

EVERDUR Anaconda's family of Copper-Silicon Alloys

MADE BY THE AMERICAN BRASS COMPANY

STRONG · WORKABLE · WELDABLE · CORROSION-RESISTANT

Surer Gland Lubrication for Centrifugal Pumps

THE Z-F GREASE SEAL eliminates that trouble spot where shaft enters casing. Applies constant positive lubrication to packing and shaft—automatically. Excessive heat, rapid wear, leakage and scoring will dissapear as the Grease Seal supplies a constant flow of lubrication when pump starts until it stops—automatically. Many other advantages, too. Write for complete description and price. Zimmer and Francescon, Moline, Ill.

ZF

At the Annual Dinner, Federation Vice-President Kenneth S. Watson presented the Bedell Award to Arthur D. Caster, Cincinnati, and the Hatfield Award to Willard W. Smith, Cambridge.

The 1958 Conference is scheduled for June 18–20, 1958 at Toledo, Ohio. Officers elected for 1957–58 were:

Chairman: William R. Taylor, Cleveland.

First Vice-Chairman: Carl Bauer, Celina.

Second Vice-Chairman: E. W. Petrich, Urbana.

FSIWA Director: H. S. Kline, Dayton.

Secretary-Treasurer: C. E. Lay, Columbus.

WARD E. CONRAD,
Secretary-Treasurer

SEWAGE TREATMENT PLANT SUPERVISORS
(CIVIL SERVICE POSITIONS)

The Department of Water and Sewers of the City of Miami, Florida, is accepting applications for the position of Sewage Treatment Plant Supervisor.

The Salary range for this position is $5,388.00 to $6,648.00. Desired qualifications: At least five (5) years previous experience in the operation of complex sewage treatment plants. Education: Graduation from high school or a vocational school with courses in chemistry and biology of sewage treatment or related subjects.

This is a Civil Service position as a shift Supervisor. (Rotating shifts.) It includes a paid vacation, sick leave, group insurance, health, welfare, and pensions plans and many other employees benefits.

Send a complete summary of your education, previous experience and personal data to C. F. Wertz, Director, Department of Water and Sewers, City of Miami, P. O. Box 316, Miami 33, Florida.

SEWAGE PLANT SUPERINTENDENT

The City of Roanoke, Virginia has available as of October 1, 1957, a position as Plant Superintendent, Sewage Treatment Plant.

Salary Range—$420.00–$540.00 per month (1956 Job Class. Comm. Report)

Position carries Pension Plan, Sick Leave, and Vacation. Retirement age 65.

Qualifications: Should have B.S. in Sanitary, Civil, or Chemical Engineering and possess at least 5 years operational experience in an activated sludge plant. (Sect. 110-3, Job Description, City of Roanoke)

Plant Data: Type: Standard Activated Sludge Process

Capacity: Design: 14.00 M.G.D. including 25% Return
Present: 11.47 M.G.D plus 39% Return

Number of Personnel: 19

Application accompanied with photograph to be made to Mr. A. S. Owens, City Manager setting forth training and experience.

CONTROL FOAM IN
YOUR SEWAGE AERATOR
WITH FINE ORGANICS'

FOAMWILT

Here is the efficient solution to foam problems—FOAMWILT —Fine Organics' low cost, easy-to-use product that not only kills off foam, but inhibits its formation.

Fine Organics' FOAMWILT possesses these outstanding properties:

1. Excellent spreading ability
2. Good "knockdown" of foam at ambient temperatures and unaffected by seasonal changes
3. Rapid travel of defoamant
4. Uniformity, stability, and small change in viscosity at temperatures from 0° to + 100° F., allowing outside storage at all temperatures (no clogging of valves and pipes, no separation)
5. Pour point: minus 25° F.

Fine Organics' FOAMWILT is economical to use too . . . it eliminates the need for expensive equipment or special training. Feed 0.5 to 1 p.p.m. of FOAMWILT with a suitable pump and watch the excellent foam control in your sewage aerator.

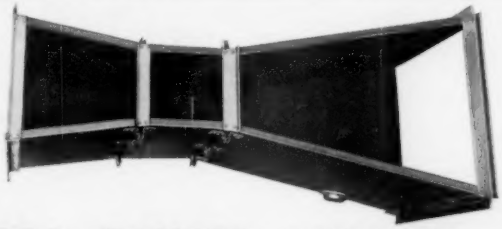
Once you use Fine Organics' FOAMWILT, you'll have the efficient solution to your foam suppression problems.

Buy Fine Organics' FOAMWILT for economical and uniformly good control of foam. Write today for full details.

FINE ORGANICS, INC.

211 EAST 19TH STREET · NEW YORK 3, N. Y.

ACCURATE!
PERMANENT!
ECONOMICAL!



PARSHALL FLUME LINERS

FABRICATED FROM "CHEMSTONE"

Chemstone flume liners are made of asbestos cement material impregnated with a special asphaltic compound under pressure. It will withstand shock, vibration and is impervious to most acids, alkaline solutions and rapid temperature changes.

Saves many hours of building forms for concrete pouring and is accurate within plus or minus 1/16". Flume liners with throats 3" to 18" are furnished completely assembled for quick, easy installation. For throats 18" to 96" the liners are furnished in two sections.

Write today for further details and specifications.

FILTRATION EQUIPMENT CORPORATION

273 HOLLENBECK STREET • ROCHESTER, NEW YORK

FSIWA SPECIAL PUBLICATIONS

ORDER FORM

Federation of Sewage and Industrial Wastes Associations
4435 Wisconsin Ave., N. W.
Washington 16, D. C.

Please send me the following publications, for which remittance is enclosed:

MANUALS OF PRACTICE

..... copies * MOP No. 1, "Occupational Hazards in the Operation of Sewage Works" (1944)
Members 25 cents; non-members 50 cents .....

..... copies * MOP No. 2, "Utilization of Sewage Sludge as Fertilizer" (1946)
Members 75 cents; non-members $1.25 .....

..... copies * MOP No. 3, "Municipal Sewer Ordinances" (1949)
Members 50 cents; non-members $1.00 .....

..... copies * MOP No. 4, "Chlorination of Sewage and Industrial Wastes" (1951)
Members $1.00; non-members $1.25 .....

..... copies * MOP No. 5, "Air Diffusion in Sewage Works" (1952)
Members $1.00; non-members $1.25 .....

..... copies * Ring Binders for numbered Manuals of Practice @ 2.00 .....

* Discount of 15% on orders for 12 or more copies.

OTHER SPECIAL PUBLICATIONS

..... copies "Uniform System of Accounts for Sewer Utilities" (1949); mimeographed; @ $5.00 .....

..... copies "Glossary—Water and Sewage Control Engineering" (1949) @ $1.00 .....

..... copies Twenty-Year Index to SEWAGE WORKS JOURNAL (1928–48) @ $4.50 .....

Total remittance enclosed .....

Name..... Member?.....
(Yes or No)

Address .....

.....
(Member Association)

DIRECTORY OF ENGINEERS

(Continued through page 456a)

ALBRIGHT & FRIEL, INC.
CONSULTING ENGINEERS

Water, Sewage, Industrial Wastes and Incineration Problems
City Planning, Highways, Bridges and Airports
Dams, Flood Control, Industrial Buildings
Investigations, Reports, Appraisals and Rates

THREE PENN CENTER PLAZA
PHILADELPHIA 2, PA.

ALVORD, BURDICK & HOWSON
Engineers
Charles B. Burdick Louis R. Howson
Donald H. Maxwell

Water Works, Water Purification, Flood Relief, Sewerage, Sewage Disposal, Drainage, Appraisals, Power Generation

Civic Opera Building Chicago

ANDERSON-NICHOLS & Company
Consulting Engineers
Water Supply, Distribution and Treatment, Industrial Waste Treatment, Sewage Collection and Disposal, Refuse Collection and Disposal, Drainage, Highways and Bridges.
Concord, N. H. Boston 14 Baltimore, Md.

JOHN J. BAFFA
Consulting Engineer
Sewerage & Sewage Treatment
Industrial Wastes Treatment
Design Plans & Specifications
Investigations & Rate Studies
75 West Street New York 6, N. Y.

MICHAEL BAKER, JR., Inc.
Consulting Engineers
Civil Engineers, Planners, and Surveyors
Municipal Engineers—Airport Design—Sewage Disposal Systems—Water Works Design and Operation—Surveys and Maps—City Planning—Highway Design—Construction Surveys—Pipe Line Surveys
Home Office: Rochester, Pa.
Branch Offices: Jackson, Miss. Harrisburg, Pa.

BAXTER AND WOODMAN
Civil and Sanitary Engineers
Water Supplies Water Treatment
Sewer Systems Sewage Treatment
Industrial Waste Treatment
Investigations
P. O. Box 166 Crystal Lake, Illinois

THOMAS W. BEAK
Consulting Biologist
Pollution Studies
Stream and Lake Surveys
Toxicity Tests
Biological and Chemical Analyses
113 Charlotte St., Ottawa, Ontario, Canada

HOWARD K. BELL
Consulting Engineers
G. S. Bell C. G. Gaither J. K. Latham
J. W. Finney, Jr., Assoc.
Sewerage Water Works
Sewage Treatment Water Purification
Refuse Disposal Swimming Pools
Industrial Wastes
553 S. LIMESTONE ST., LEXINGTON, KY.

ONLY $66 PER YEAR
is the cost of a professional listing in this space. A card here will identify your firm with the specialized sewage and industrial wastes field and will afford maximum prestige!

BETZ LABORATORIES, INC.
Consulting Engineers
Industrial Waste
Industrial Water
Analysis Design
Investigations Operation
Gillingham & Worth Sts. Philadelphia 24, Pa.

It pays to secure competent and experienced engineering advice!

DIRECTORY OF ENGINEERS

BLACK & VEATCH
Consulting Engineers
Sewage - Water - Electricity - Industry
Reports, Design, Supervision of Construction, Investigations, Valuation and Rates
1500 Meadow Lake Parkway
Kansas City 14, Mo.

BOGERT AND CHILDS
Consulting Engineers
CLINTON L. BOGERT — FRED S. CHILDS
IVAN L. BOGERT — DONALD M. DITMARS
ROBERT A. LINCOLN — CHARLES A. MANGANARO
WILLIAM MARTIN
Water & Sewage Works — Refuse Disposal
Drainage — Flood Control
Highways and Bridges — Airfields
145 East 32nd Street, New York 16, N. Y.

BOWE, ALBERTSON & ASSOCIATES
Engineers
Sewage and Water Works—Industrial Wastes—Refuse Disposal—Municipal Projects—Industrial Buildings—Reports—Plans—Specifications—Supervision of Construction and Operation—Valuations—Laboratory Service
75 West Street — New York 6, N. Y.

BOYLE ENGINEERING
Consulting Engineers
Water — Sewers — Streets
Structures — Surveys
Reports—Special Districts
331 Spurgeon Bldg., Santa Ana, Calif. — 3913 Ohio, Rm. 200, San Diego 4, Calif.

CONSULTING ENGINEERS!
If you specialize in sewage and industrial waste disposal problems, prospective clients will expect to find your card in the Directory of Engineers contained in the . . .
Official Professional Journal of the Sewage and Industrial Wastes Field!

BROWN AND CALDWELL
CIVIL AND CHEMICAL ENGINEERS
WATER - SEWAGE - INDUSTRIAL WASTE
CONSULTATION - DESIGN - OPERATION
CHEMICAL AND BACTERIOLOGICAL LABORATORIES
66 MINT STREET — SAN FRANCISCO 3

BROWN ENGINEERING CO.
Consulting Engineers
Waterworks, Sewage Disposal, Airports
Street Improvements, Power Plants
Electric Distribution, Rates
K. P. BUILDING — DES MOINES, IOWA

FLOYD G. BROWNE AND ASSOCIATES
F. G. Browne — S. W. Kuhner
W. G. Smiley — C. R. Martin
G. M. Hinkamp — W. H. Kuhn
Consulting Engineers
Water - Sewage - Industrial Wastes - Power
Reports, Designs, Construction Supervision, Investigations, Laboratory
123-125 W. Church Street — Marion, Ohio

BUCK, SEIFERT AND JOST
Consulting Engineers
Specializing in Sewerage and Sewage Disposal, Water Supply and Water Purification, Valuations and Reports
Chemical and Biological Laboratories
112 East 19th Street — New York 3, N. Y.

Your firm should be listed here
. . . the most complete Directory available of consultants specializing in sewage and industrial wastes treatment.

BURGESS & NIPLE
Civil and Sanitary Engineers
Established 1908
Sewage and industrial wastes disposal
Investigations, reports, design, rates
Laboratories, Plant Supervision
2015 W. Fifth Ave. — Columbus 12, Ohio

Take advantage of the services of these outstanding consultants!

BURNS & McDONNELL

Engineers - Architects - Consultants

KANSAS CITY, MO.
P.O. Box 7088
Phone: DElmar 3-4375

DIRECTORY OF ENGINEERS

CAMP, DRESSER and McKEE
Consulting Engineers
Water Works and Water Treatment
Sewerage and Sewage Treatment
Municipal and Industrial Wastes
Investigations and Reports
Design and Supervision
Research and Development
Flood Control
6 Beacon St. Boston 8, Mass.

CAPITOL ENGINEERING CORPORATION
Engineers—Constructors—Management
SEWAGE SYSTEMS WATER WORKS
Designs and Surveys Roads and Streets
Planning Airports
Bridges Dams
Executive Offices
DILLSBURG, PENNSYLVANIA

THE CHESTER ENGINEERS
Water Supply and Purification
Sewage Treatment
Industrial Waste Disposal and Recovery
Power Plants–Incineration–Gas Systems
Valuations–Rates–Management
Laboratory
601 Suismon St., Pittsburgh 12, Penna.

CHAS. W. COLE & SON
Engineers ~ Architects
Municipal Industrial
Commercial
220 W. LaSalle St., South Bend, Ind.
Phone 4-0127

CONSOER, TOWNSEND & ASSOCIATES
Water Supply—Sewerage—Flood Control & Drainage—Bridges—Ornamental Street Lighting—Paving—Light and Power Plants. Appraisals.
360 East Grand Ave. Chicago 11, Ill.

CONSULTING BIOLOGISTS
Thomas Dolan Charles B. Wurtz
Freshwater and Marine Pollution Surveys
Biological Surveys of Sewage and Industrial Wastes
Effects of Pollution
Self-Purification Capacity Studies
Analyses, Chemical and Bacteriological
Bioassays
Investigations and Reports
610 Commercial Trust Bldg.
Philadelphia 2, Pa.

COTTON, PIERCE, STREANDER, INC.
Associated Consulting Engineers
Water Supply, Treatment, Distribution, Sewerage, Sewage Treatment, Refuse Disposal
132 Nassau Street, New York, N. Y.
55 Caroline Road, Gowanda, N. Y.
2718 Garfield Street, Hollywood, Fla.
Colon 106, Havana, Cuba

ONLY $66 PER YEAR
is the cost of a professional listing in this space. A card here will identify your firm with the specialized sewage and industrial wastes field and will afford maximum prestige!

Your firm should be listed here
. . . the most complete Directory available of consultants specializing in sewage and industrial wastes treatment.

Damon & Foster
Consulting Civil Engineers and Surveyors
Sewerage, Sewage Disposal, Water Supply, Surveys, Land Subdivision, City and Town Planning, Reports, Design, Supervision
Sharon Hill, Pennsylvania

It pays to secure competent and experienced engineering advice!

DIRECTORY OF ENGINEERS

CATHODIC PROTECTION

Engineering—Surveys—Design—Installation

Electro Rust-Proofing Corp. (N.J.)
Belleville 9, New Jersey

FAY, SPOFFORD & THORNDIKE, INC.
ENGINEERS

Water Supply and Distribution—Drainage
Sewerage and Sewage Treatment
Airports—Bridges—Turnpikes
Port and Terminal Works—Industrial Bldgs.

BOSTON, MASSACHUSETTS

CONSULTING ENGINEERS!

If you specialize in sewage and industrial waste disposal problems, prospective clients will expect to find your card in the Directory of Engineers contained in the . . .

Official Professional Journal of the Sewage and Industrial Wastes Field!

FINKBEINER, PETTIS & STROUT

CARLETON S. FINKBEINER CHARLES E. PETTIS
HAROLD K. STROUT

Consulting Engineers

Reports, Designs, Supervision,
Water Supply, Water Treatment, Sewerage,
Sewage Treatment, Wastes Treatment
Valuations & Appraisals

518 Jefferson Avenue Toledo 4, Ohio

FREESE & NICHOLS
FORT WORTH, TEXAS

FREESE, NICHOLS & TURNER
HOUSTON, TEXAS

Industrial and Municipal Engineering—Water Supply and Purification—Sewerage and Industrial Waste Treatment—Highways and Structures—Dams—Drainage Works—Airports—Investigations—Valuation—Design and Supervision

FROMHERZ ENGINEERS

Structural - Civil - Sanitary

Four Generations Since 1867

Water Supply; Sewerage; Structures; Drainage; Foundations
Industrial Waste Disposal
Investigations; Reports; Plans and Specifications; Supervision

816 Howard Avenue New Orleans 12, La.

EDWARD A. FULTON

Consulting Engineers

Investigations, Reports, Valuations, Design and Construction—Water Supply and Purification Plants; Sewerage and Sewage Treatment Works; Municipal Paving and Power Developments; Dams and Flood Control

3209 Brown Road Saint Louis 14, Missouri

GANNETT FLEMING CORDDRY & CARPENTER, INC.
ENGINEERS

Dams, Water Works, Sewage, Industrial Wastes & Garbage Disposal, Highways, Bridges & Airports, Traffic & Parking—Appraisals, Investigations & Reports.

HARRISBURG, PENNA.

Branch Offices: Pittsburgh, Pa. Philadelphia, Pa. Daytona Beach, Fla.

GARRITY & MOSHER

Engineers

LEO V. GARRITY L. W. MOSHER

Municipal and Industrial Water and Sewage Works
Water System Analyses
Tunnels and Foundations
Reports, Designs, Plans and Specifications

14050 W. McNichols Rd. Detroit 35, Mich.

GILBERT ASSOCIATES, INC.
Engineers and Consultants

Water Supply and Purification
Sewage and Industrial Waste Treatment
Chemical Laboratory Service
Investigations and Reports

607 Washington St.
New York READING, PA. Washington

Glace & Glace, Inc.
Civil and Sanitary Engineers

Sewerage and Sewage Treatment
Water Supply and Purification
Industrial Wastes Disposal

Design, Construction and Supervision of Operation

1001 N. Front Street Harrisburg, Pa.

Take advantage of the services of these outstanding consultants!

GREELEY & HANSEN
Engineers
Samuel A. Greeley — Paul Hansen (1920–1944)
Paul E. Langdon — Kenneth V. Hill
Thomas M. Niles — Samuel M. Clarke
Water Supply, Water Purification
Flood Control, Drainage, Refuse Disposal
Sewerage, Sewage Treatment
220 S. State Street, Chicago 4

DIRECTORY OF ENGINEERS

FRANK E. HARLEY AND ASSOCIATES
Consulting Engineers
Sewerage and Sewage Treatment
Water Supply and Purification
Industrial Wastes and Garbage Disposal
Municipal Improvements — Town Planning Surveys
Design, Supervision and Operation
260 Godwin Avenue — Wyckoff, N. J.

HARRIS-DECHANT ASSOCIATES
Frederick H. Dechant — Consulting Engineer
Water Works, Industrial Wastes, Sewerage,
Recovery Processes, Hydraulic Works,
Natural Gas Transmission and Distribution.
123 S. Broad St. — Philadelphia 9, Pa.

ONLY $66 PER YEAR
is the cost of a professional listing in this space. A card here will identify your firm with the specialized sewage and industrial wastes field and will afford maximum prestige!

HASKINS, RIDDLE & SHARP
Consulting Engineers
Water—Sewage & Industrial Wastes—Hydraulics
Reports, Design, Supervision of Construction
Appraisals, Valuations, Rate Studies
1009 Baltimore Ave. — Kansas City 5, Mo.

HAVENS AND EMERSON
W. L. Havens — A. A. Burger
J. W. Avery — H. H. Moseley
F. S. Palocsay — E. S. Ordway
F. C. Tolles, Consultant
Consulting Engineers
WATER, SEWERAGE, GARBAGE, INDUSTRIAL WASTES, VALUATIONS—LABORATORIES
Leader Bldg. — Woolworth Bldg.
Cleveland 14, O. — New York 7, N. Y.

HAZEN AND SAWYER
ENGINEERS
RICHARD HAZEN — ALFRED W. SAWYER
Municipal and Industrial Water Supply
Purification and Distribution
Sewage Works and Waste Disposal
Investigations, Design,
Supervision of Construction and Operation
122 East 42nd Street — New York 17, N. Y.

HENNINGSON, DURHAM & RICHARDSON, INC.
Consulting Engineers and Architects since 1917
for more than 700 cities and towns
Water Works, Light and Power, Sewers, Sewage Treatment, Reports, Flood Control, Appraisals, Drainage, Industrial Works
2962 Harney St. — Omaha 2, Nebraska

HORNER & SHIFRIN
Consulting Engineers
W. W. HORNER — E. E. BLOSS
V. C. LISCHER
Airports — Hydraulic Engineering — Sewerage and Sewage Treatment — Water Supply — Municipal Engineering — Reports
Shell Building, St. Louis 3, Missouri

GRIT AND HEAVY SLUDGE REMOVAL
CONCRETE RESTORATION
SEWAGE AND WATER WORKS
HUDSON-RUMSEY CO., INC. — 1679 Niagara St.
Professional Engineers — Buffalo 7, N. Y.

It pays to secure competent and experienced engineering advice!

DIRECTORY OF ENGINEERS

INDUSTRIAL WASTE DISPOSAL CORPORATION
Consultants
Oceanographers — Chemists — Engineers
Deep Sea Disposal
Plant Site and Outfall Surveys
Biological and Chemical Analyses
Research — Waste Treatment
Pollution
Drawer 150 Baytown, Texas

The Jennings-Lawrence Co.
Civil and Municipal Engineers
Consultants
Water Supply, Treatment & Distribution
Sewers & Sewage Treatment
Reports—Design—Construction
1392 King Ave. Columbus 12, Ohio

JONES, HENRY & WILLIAMS
Consulting Sanitary Engineers
Water Works
Sewerage & Treatment
Waste Disposal
Security Bldg. Toledo 4, Ohio

KAIGHIN AND HUGHES ENGINEERS
INDUSTRIAL WASTES DIVISION
E. B. Besselievre, Mgr.
STUDY - DESIGN - EQUIPMENT - CONSTRUCTION
1080 Atlantic Ave. Toledo 1, Ohio

KEIS & HOLROYD
Consulting Engineers
Formerly Solomon & Keis
Since 1906
Water Supply and Purification, Sewerage and Sewage Treatment, Garbage and Refuse Disposal and Incineration, Industrial Buildings.
TROY, NEW YORK

ENGINEERING OFFICE OF CLYDE C. KENNEDY
offers
COMPLETE ENGINEERING SERVICE
Investigations, Reports, Design
Supervision of Construction and Operation
Sewerage, Sewage Treatment and Industrial Waste Disposal
Chemical and Biological Laboratory
604 MISSION ST., SAN FRANCISCO 5

MORRIS KNOWLES Inc.
Engineers
Water Supply and Purification, Sewerage and Sewage Disposal, Valuations, Laboratory, City Planning.
1312 Park Bldg. Pittsburgh 22, Pa.

KOEBIG AND KOEBIG
Consulting Engineers Since 1910
Investigations, Reports, Designs
Sewerage & Sewage Treatment
Water Supply & Water Treatment
Municipal Engineering
3242 West 8th Street, Los Angeles 5, Calif.

LANNING
Sanitary Engineering Co., Inc.
Consulting Engineers
Water, Sewage, Drainage, and Industrial Wastes
Reports, Designs, Supervision Of Construction and Operation
Chemical & Biological Laboratory
1100 South Broad St. Trenton, N. J.

Wm. S. Lozier Co.
Consulting Engineers
Sewerage, Sewage Disposal, Water Supply, Water Purification, Refuse Disposal
10 Gibbs Street Rochester, 4, N. Y.

GEORGE B. MEBUS, Inc.
Consulting Engineers
Water Supply Sewage Treatment
Industrial Waste Treatment
BROAD STREET TRUST BUILDING
GLENSIDE, PA.

Take advantage of the services of these outstanding consultants!

METCALF & EDDY
Engineers
Water, Sewage, Drainage, Refuse and Industrial Wastes Problems
Laboratory Valuations
Airports
Statler Building
Boston 16

DIRECTORY OF ENGINEERS

Nussbaumer, Clarke & Velzy, Inc.
Consulting Engineers
SEWAGE TREATMENT—WATER SUPPLY
INCINERATION—DRAINAGE
INDUSTRIAL WASTE TREATMENT
APPRAISALS
327 Franklin St., Buffalo, N. Y.
500 Fifth Ave., New York 36, N. Y.

PARSONS, BRINCKERHOFF, HALL & MACDONALD
G. Gale Dixon, Associate
Civil and Sanitary Engineers
Water, Sewage, Drainage and Industrial Waste Problems.
Structural — Power — Transportation
51 Broadway **New York 6, N.Y.**

E. C. PATTEE
Consulting Chemical Engineer
Industrial Waste Disposal
Process Development, Surveys & Design
Provident Bank Bldg., Cincinnati 2, Ohio

PIATT AND DAVIS
WM. M. PIATT **P. D. DAVIS**
Consulting, Designing, and Supervising Engineers
Water Works, Sanitary Sewers, Water Purification
Sewage Treatment, Public Buildings, Streets
Power Plants, Electrical Distribution
Reports and Appraisals
One Eleven Corcoran St. Bldg. **Durham, N. C.**

MALCOLM PIRNIE ENGINEERS
Civil and Sanitary Engineers
Malcolm Pirnie **Ernest W. Whitlock**
Robert D. Mitchell **Carl A. Arenander**
Malcolm Pirnie, Jr.
Investigations, Reports, Plans
Supervision of Construction and Operations
Appraisals and Rates
25 West 43rd Street **New York 36, N. Y.**

LEE T. PURCELL
Consulting Engineer
Water Supply & Purification; Sewerage & Sewage Disposal; Industrial Wastes; Investigations & Reports; Design; Supervision of Construction & Operation
Analytical Laboratories
36 De Grasse St. **Paterson 1, N. J.**

RESOURCES RESEARCH, INC.
Municipal and Industrial Air Pollution Control,
Water Supply, Sewage Disposal, Public Health
Reports, Investigations, Research
LOUIS C. MCCABE, *Pres.*
4435 Wisconsin Ave. **Washington 16, D. C.**

THOMAS M. RIDDICK
Consulting Engineers and Chemists
Municipal and Industrial Water Purification,
Sewage Treatment Plant Supervision,
Industrial Waste Treatment
Laboratories for Chemical and Bacteriological Analyses
369 E. 149th St. **New York 55, N.Y.**

RIPPLE AND HOWE, Inc.
Consulting Engineers
O. J. RIPPLE V. A. VASEEN B. V. HOWE
Appraisals—Reports
Design—Supervision
Water Works Systems, Filtration and Softening Plants, Reservoirs and Dams, Sanitary and Storm Sewers, Sewage Treatment Plants, Refuse Disposal, Airports
833-35 Twenty-Third St. **Denver 5, Colorado**

Robert and Company Associates
Engineering Division
ATLANTA
Water Supply - - - - - - - - Incinerators
Sewage Disposal - - - - - - - Power Plants

It pays to secure competent and experienced engineering advice!

DIRECTORY OF ENGINEERS

RUSSELL AND AXON
Consulting Engineers
Civil — Sanitary — Structural
Industrial — Electrical
Rate Investigations
408 Olive St., St. Louis 2, Mo.
Municipal Airport, Daytona Beach, Fla.

SMITH and GILLESPIE
Consulting Engineers
All types of Municipal Public Works & Utilities
Complete Services
P. O. Box 1048, Jacksonville, Fla.

STANLEY ENGINEERING COMPANY
Consulting Engineers
Hershey Building, Muscatine, Iowa
208 S. LaSalle Street, Chicago 4, Illinois

ALDEN E. STILSON & ASSOCIATES
Limited
Consulting Engineers
Water Supply—Sewerage—Waste Disposal
Bridges—Highways—Industrial Buildings
Studies—Surveys—Reports
245 N. High St. Columbus 15, Ohio

HENRY W. TAYLOR
Consulting Engineer
Water Supply, Sewerage
Refuse Disposal, Incineration
Industrial Developments
151 W. Merrick Rd. Freeport, N.Y.

J. STEPHEN WATKINS
J. S. Watkins G. R. Watkins
CONSULTING ENGINEERS
Municipal and Industrial Engineering, Water Supply and Purification, Sewerage and Sewage Treatment, Highways and Structures, Reports, Investigations and Rate Structures.
251 East High Street Lexington, Kentucky
Branch Office
4726 Preston Highway Louisville, Kentucky

WESTON, ECKENFELDER AND ASSOCIATES
Consultants
Engineers—Biologists—Chemists
Industrial Wastes
Stream Pollution—Air Pollution
Water—Sewage
Surveys—Research—Development—Process Engineering—Operation Supervision—Analyses—Evaluations and Reports
Newtown Square Pennsylvania

WESTON & SAMPSON
Consulting Engineers
Water Supply Water Purification
Corrosion Control
Sewerage, Sewage and Industrial Wastes Treatment
Stream Pollution Studies
Supervision, Valuation
Laboratory
14 Beacon Street Boston 8, Mass.

WHITMAN & HOWARD
Engineers (Est. 1869)
Sewerage, Sewage Disposal, Municipal and Industrial Development Problems, Water Supply, Water Purification, Water Front Improvements, Investigations, Reports, Designs, Supervision, Valuations
89 Broad Street, Boston, Mass.

Your firm should be listed here

. . . the most complete Directory available of consultants specializing in sewage and industrial wastes treatment.

WHITMAN, REQUARDT & ASSOCIATES
Engineers—Consultants
Civil — Sanitary — Structural
Mechanical — Electrical
Reports, Plans, Supervision, Appraisals
1304 St. Paul Street Baltimore 2, Maryland

Take advantage of the services of these outstanding consultants!

INDEX TO ADVERTISERS

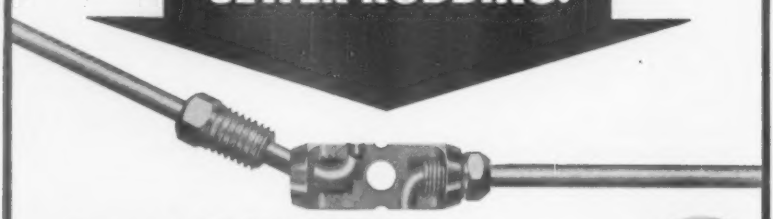
	Page
American Brass Company	445a
American Concrete Pressure Pipe Association	431a
Brown Company	433a
Builders-Providence Division of B-I-F Industries	Inside Front Cover
Burgess-Manning Company (Penn Instruments Division)	426a
Cast Iron Pipe Research Association	416a, 417a
Chain Belt Company	434a
Chapman Valve Manufacturing Company	427a
Chicago Pump Company	409a
Cloroben Chemical Corporation	430a
Clow, James B., and Sons	419a
Combustion Engineering (Raymond Division)	411a
Dorr-Oliver Incorporated	440a
Durajoint Technical Information Center	429a
Filtration Equipment Corporation	447a
Fine Organics, Incorporated	447a
Flexible Incorporated	458a
Foxboro Company	432a
Inertol Company, Incorporated	420a
Infilco Incorporated	415a
Jeffrey Manufacturing Company	418a
Johns-Manville	421a
Lock Joint Pipe Company	Inside Back Cover
National Water Main Cleaning Company	428a
Nichols Engineering and Research Corporation	422a
Pacific Flush Tank Company	438a
Portland Cement Association	436a
Simplex Valve and Meter Company	413a
Snow Gates and Valves	442a
Stewart, W. H., Inc.	444a
United States Pipe and Foundry Company	424a, 425a
Vapor Recovery Systems Company	441a
Walker Process Equipment Incorporated	443a
Wallace and Tiernan Incorporated	Back Cover
Wheeler, C. H., Manufacturing Company	435a
Worthington Corporation	437a
Yeomans Brothers Company	423a
Zimmer and Francescon	446a

DIRECTORY OF ENGINEERS, 449a–456a

Albright & Friel, Inc.
Alvord, Burdick & Howson
Anderson-Nichols & Company
Baffa, John J.
Baker, Michael, Jr., Inc.
Baxter & Woodman
Beak, Thomas W.
Bell, Howard K.
Betz Laboratories, Inc.
Black & Veatch
Bogert and Childs
Bowe, Albertson & Associates
Boyle Engineering
Brown & Caldwell
Brown Engineering Co.
Browne, Floyd G., and Associates
Buck, Seifert & Jost
Burgess & Niple
Burns & McDonnell
Camp, Dresser & McKee
Capitol Engineering Corp.
Chester Engineers, The
Cole, Chas. W. & Son
Consoer, Townsend & Associates
Consulting Biologists: Dolan and Wurtz
Cotton, Pierce, Streander, Inc.
Damon & Foster
Electro Rust-Proofing Corp. (N. J.)
Fay, Spofford & Thorndike
Finkbeiner, Pettis & Strout
Freese & Nichols
Fromherz Engineers
Fulton, Edward A.
Gannett Fleming Corddry & Carpenter, Inc.
Garrity & Mosher
Gilbert Associates, Inc.
Glace & Glace, Inc.
Greeley & Hansen
Harley, Frank E., and Associates
Harris-Dechant Associates
Haskins, Riddle & Sharp
Havens and Emerson
Hazen & Sawyer
Henningson, Durham & Richardson, Inc.
Horner & Shifrin
Hudson-Rumsey Co., Inc.
Industrial Waste Disposal Corporation
Jenning-Lawrence Co.
Jones, Henry & Williams
Kaighin and Hughes
Keis & Holroyd
Kennedy, Clyde C.
Knowles, Morris, Inc.
Koebig & Koebig
Lanning Sanitary Engineering Co., Inc.
Lozier, Wm. S., Company
Mebus, George B., Inc.
Metcalf & Eddy
Nussbaumer, Clarke & Velzy, Inc.
Parsons, Brinckerhoff, Hall & Macdonald
Pattee, E. C.
Piatt & Davis
Pirnie, Malcolm, Engineers
Purcell, Lee T.
Resources Research, Inc.
Riddick, Thomas M.
Ripple & Howe
Robert and Company Associates
Russell & Axon
Smith & Gillespie
Stanley Engineering Company
Stilson, Alden E., & Associates
Taylor, Henry W.
Watkins, J. Stephen
Weston, Eckenfelder and Associates
Weston & Sampson
Whitman & Howard
Whitman, Requardt & Associates

PATRONIZE OUR ADVERTISERS—whose support makes possible the publication of this journal. *When writing advertisers be sure to mention SEWAGE AND INDUSTRIAL WASTES.*

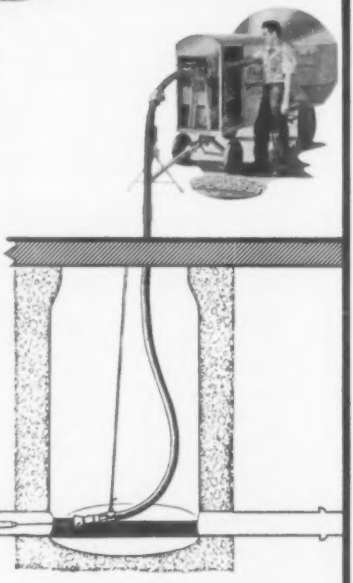
It's FLEXICROME FOR HIGH SPEED SEWER RODDING!



25 years ago "**Flexible**" Steel Sewer Rods took the men out of the sewers. When power turning was introduced, **FLEXICROME STEEL** had to be developed to withstand the added stresses and strains.

FLEXICROME is the only alloy steel produced exclusively for sewer rodding. There is no known equal, as confirmed by independent laboratory reports. As an added "life preserver," a heat fused, pore sealing coating is applied to improve sewer acid resistance. **FLEXICROME GRoovED COUPLINGS** are also specially designed to **last longer** and couple and uncouple in half the time.

That's why some cities report up to 200,000 feet of sewer rodding with **FLEXICROMES** before replacement.



FLEXIBLE INC.

1005 SPENCERVILLE ROAD, LIMA, OHIO
3786 DURANGO AVE., LOS ANGELES 34, CALIF.
351 W. JEFFERSON BLVD., DALLAS, TEXAS

For Superior, Infiltration-Proof Sewer Lines

Snap gasket on spigot end. Push spigot home. Joint still tight when deflected.

LOCK JOINT ROLLER SUSPENSION PIPE WITH LOCK JOINT FLEXIBLE JOINT RUBBER GASKET

Many engineers who demand the best in sewer lines specify Lock Joint Roller Suspension Pipe for their projects. In addition to its unusual strength, this concrete pipe offers premiums in durability, economy of installation and excellence of joint structure.

Where a tight line is imperative, you will get best results by sealing Roller Suspension Pipe's precision made joint ends with Lock Joint *Flexible Joint* Rubber Gaskets. These gaskets require no joint compound or adhesive. Merely snap the gasket in place on the spigot end and force the spigot "home" in the bell. The joint thus formed will not only reduce your infiltration problems to a minimum, but will also have such a degree of flexibility as to accommodate unusual deflections from ground settlement or other sources without endangering the complete tightness of the line.

LOCK JOINT PIPE CO.
East Orange, N. J.

Sewer and Culvert Pipe Plants:

Kenilworth, New Jersey	Valley Park, Missouri	Cheyenne, Wyoming
Hartford, Connecticut	N. Kansas City, Missouri	Casper, Wyoming
New Haven, Connecticut	Tulsa, Oklahoma	Tucumcari, New Mexico
Beloit, Wisconsin	Oklahoma City, Oklahoma	Hato Rey, Puerto Rico
Chicago, Illinois	Wichita, Kansas	Ponce, Puerto Rico
Rock Island, Illinois	Denver, Colorado	Caracas, Venezuela

Also Great Lakes Concrete Pipe Company with plants at Buffalo, N. Y. and Henrietta, N. Y.

W&T Chlorinators with chlorine evaporators and master control panel (insert) used at the D.C. Sewage Treatment Plant.

DISTRICT OF COLUMBIA SEWAGE TREATMENT PLANT...

modern concepts of sewage chlorination control

Design of the Washington, D. C. Sewage Treatment Plant utilizes modern concepts of sewage chlorination control. W&T water diaphragm, high capacity chlorinators at the Plant are controlled from remote chlorine rate setting stations which operate by push button.

Remote control stations allow plant operators to change chlorine feed rates without leaving the operating center of the plant. Remote rate of feed indicators at the stations show the rate at which chlorine is being fed and immediately show changes in the rate of feed. W&T Chlorine Flow Recorders give a permanent record of the daily chlorine feed of each chlorinator and also the total amount of chlorine fed to each point of application.

In addition to remote chlorinator control, W&T offers many other types of accurate and effective controls which can help the operation of your plant. From simple intermittent start-stop operation through automatic proportioning of chlorine feed to sewage flow, program control based on plant flow patterns, and ORP recorder-controllers, W&T can answer your chlorinator control problem.

"Make Your First Choice Equipment That Lasts"

WALLACE & TIERNAN INCORPORATED

25 MAIN STREET, BELLEVILLE 9, NEW JERSEY

S-102

LANCASTER PRESS, INC., LANCASTER, PA.